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A
PHILOSOPHICAL INQUIRY
INTO THE
NATURE AND PROPERTIES
OF
COMMON WATER:
WITH ANNEXED OBSERVATIONS
ON ITS
Medicinal Qualities, &c.

BY
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AND
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> “ Eſt animorum ingeniorumque noſtrorum, naturale quod-
> “ dam quaſi pabulum conſideratio contemplatioque naturæ.
> CICERO.”

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TO

JOSEPH BLACK, M. D.

PROFESSOR OF CHEMISTRY

IN THE

UNIVERSITY OF EDINBURGH;

The ſubſequent Sheets are reſpectfully Inſcribed;

As a public Teſtimony, and grateful Acknowledgment of paſt Favors, conferred upon

His much obliged,

And

Moſt humble Servant,

THE AUTHOR.

Newport,
Iſle of Wight,
Sept. 1, 1789.

PREFACE.

THE following little Tract ſeeks protection at the bar of criticiſm; yet, not without a conſiderable ſhare of diffidence on the part of the Author.

Self-amuſement was once the ſole purport of theſe inquiries; but, proceeding from one particular to another, the ſubject advanced a-pace. Its importance, therefore, in many reſpects, and withal a deſire of rendering it extenſively uſeful, gave birth to the preſent Publication; and the Compiler flatters himſelf, that he ſhall, at leaſt, be juſtified by the motives, if not, by the ſucceſs, of his undertaking: thus actuated, he affects not otherwiſe to apologiſe for his imperfections,

imperfections, than by obſerviug, that, as having ſtruck out into an intricate path of ſcience, ſomewhat new in matter as well as form, errors become, in ſome meaſure, unavoidable. The candid reader is the ſooner inclined to admit this plea, when aſſured, that the Writer was precluded, by his ſituation, from enjoying the leaſt perſonal interview with thoſe who are taken up in ſimilar purſuits; and conſequently was reduced to the alternative of either ſetting aſide his deſign, or proſecuting it in ſolitude, by the un-aſſiſted efforts of his own application.

The arrangement of the Work is ſuch as was ſuggeſted by the ſubjects themſelves: order, ſimplicity, aud perſpicuity, make the principal object throughout; and elegance is ſacrificed to brevity. Though, after all the pains beſtowed upon the performance, its being void of incorrectneſs, or indeed miſrepreſentations, is beyond what the fondeſt wiſhes of the Author, can ſeduce him to believe. Nevertheleſs, is willing to think, he has here exhibited a more connected, and diſcurſive view of the philoſophy of water, than was ever attempted by any perſon before him; and ſhould this ſame reflection, prompt others, of far ſuperior merit,

merit, to engage in ſomething better of the kind, his own fruitleſs endeavours will be amply recompenſed.

The labour of the moſt diligent Collector, muſt, however, be ultimately appreciated, by the value of the materials offered to his choice: So,

> " ——————— if vain the toil,
> " We ought to blame the culture, not the ſoil."

A
Philoſophical Enquiry, &c.

INTRODUCTION.

AMONG all the purſuits, which incidentally call forth the abilities of philoſophical men, no one, 'tis preſumed, has a more deſerving claim to their attention than that here propoſed.

The properties and effects of water, are ſurely concerns of great and general importance; and, whether regarded in a purely ſpeculative, medical, or œconomical ſenſe, we feel deeply intereſted in the enquiry.

Little ſoever as we are converſant about the principles of water, when viewed as an entire body, it is familiar in the extreme to our limited comprehe[illegible] We behold with admiration its tranſparency in a ſpring, and its poliſhed ſurface on the banks of a river; the mobility by which it rolls along the murmuring brook, and the reſtleſs motion of its waves in the tempeſtuous ocean.

Morever, we perceive the ſame fluid employed as a moſt extenſive and powerful agent in the univerſe.

If we tranſport ourſelves, in imagination, into the vaſt receſſes of the ſubterranean regions, we can obſerve this benign element acting in ſilence in the formation of the ſeveral minerals. It further riſes in vapor, under the appearance of clouds; theſe again deſcend in refreſhing ſhowers, to repleniſh the earth; and, upon occaſions, aſſume the form of ſnow and hail, for the preſervation of the tender vegetable from intenſe and mortal colds. Nor is animal exiſtence leſs dependent upon Water: nutrition, circulation, ſecretion, and excretion are ſubſervient to its laws. The wiſe purpoſes it ſerves, not only in the mechanic arts and manufactures, and in trade, as being the vehicle by which we exerciſe merchandize with the remoteſt nations, but in all animal operations, render it of eſſential benefit to our eaſe and convenience.

In a word, to it all mankind boaſt an equal poſſeſſion, as being that which avarice cannot deprive us of, nor power monopolize *.

When we ſuperficially ſurvey the ſplendid ſcenes around us, and ſee the numberleſs tribes of animals, plants, minerals, and meteors; the manner they are diverſified in their qualities; the wonderful variety that obtains amongſt them, with reſpect to colour, figure, ſolidity, humidity, elaſticity, taſte, and order, we might readily infer, that an infinity of materials engage in their compoſition. But, notwithſtanding this apparent diverſity of

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* "Aqua eſt univerſale illud ſolvens, quod omnis generis ſolidas partes dividit, diſcerpit imbibit et ſecum vehit atque tranſportat. Unde variarum in natura mutationum cauſa exiſtit, ſiquidem ſine aqua nulla generatio, fæcundatio, nutritio, vel auctio in omnibus naturæ regnis celebrari poteſt. Sine aqua nullum animal vivit; nullaque humorum vel ſanguinis progreſſio in vaſis, vel ſecretio, aut inutilium excretio perficitur. Si ſolida corpora, ut metalla mineralia, vel lapides ſunt diſſolvenda, id ope aquæ fiat neceſſe eſt. Nulla putredo aut corruptio ſine humido conſpicitur; neque remediorum in corpora humana operatio, aut liquidi in ſolidum actio ſine aquæ adminiculo contingit. Alimenta ſicca et ſolida ſine fluidis et humidis omni utilitate et uſu deſtituuntur. Jacemus in artibus mechanicis, œconomicis, arte tinctoria, re coquaria uſum aquarum eſſe ſumme neceſſarium."

Oper. Hoffman, tom. iv. *lib.* 2.

bodies,

bodies, the perpetual mutation of one thing into another, is to be ſought for in permanent and unalterable matter, *ab origine*. From the earlieſt accounts of time, unqueſtionably the productions of nature were ſimilar to thoſe of the preſent æra; and their conſtancy and invariability of properties have continued preciſely the ſame always; ſo that we are not preſented with a multitude of principles, but only an endleſs variety, reſulting from the different aſſociations of a few.

Such obvious reflections on the tenor and courſe of nature, had long ſince ſuggeſted to philoſophers an idea of primary elements. Thales, the Mileſian of old, one of the ſeven ſages of Greece, held that all things were derived from Water, and eſteemed it as the only principle in nature. Anaximander beſtowed upon Earth the appellation. According to Anaximenes, Air merited this rank. At length Empedocles, Democritus, with others, and, in the ſucceeding age, the Ariſtotelians, endeavoured to accommodate theſe prevailing theories, by aſſigning four kinds of elementary matter, each of which they conceived was naturally diſpoſed to maintain its own ſituation. Thus, that Earth, as the heavieſt, occupied the lower region; Water, as coming next to it in gravity, took to rather a more elevated ſtation; Air, being ſtill lighter, retained the middle ſpace; whilſt Fire, the moſt ſubtle of all, receded to a greater diſtance, and was ſuppoſed to conſtitute the planetary world. So all arranged in the places wherein their ſpecific gravity ſpontaneouſly fixed them. After this method they went on expounding many of the moſt ſtriking phenomena; and, though far from being deſtitute of beauty and propriety, we yet have reaſon to be diſſatified with them. Experiments, now proſecuting with unwearied diligence, both at home and abroad, imply a probability that Air, Water, and Earth, hitherto deemed elements, are ſimply one and the ſame, only differently modified by the acceſſion of heat.

Whatever we underſtand by heat, it plainly is the main ſpring of activity, and real cauſe of all the changes on our globe, upon which the viciſſitudes of day and night, winter and ſummer, invariably depend, and by whoſe nice adjuſtment, water is ſet in motion, and entirely directed.

Now, having indulged in theſe preliminary remarks, I ſhall undertake to conſider water as exhibited to us under all its ſeveral ſtates of aggregation.

I. WATER in a State of Solidity.

It's Converſion into Earth.

WATER is reputed to undergo this change in various ways; as by the functions of vegetables, trituration, and diſtillation.

It was an ancient opinion, expreſſed by Ariſtotle, that the ocean has gradually deſerted the earth, and, conſequently, the latter is daily increaſing. Newton, Linnæus, with other naturaliſts, countenanced this aſſertion; and, in proof of the allegation, contend for the actual converſion of water into earth upon the principles of vegetation. But, whether in reality theſe differ materially in quantity from what they did ſome thouſand years ago, is not eaſy to aſcertain. It is true, in inland countries, and on many of our coaſts, there are evident traces of the ſea having retired, from the different ſtrata of marine productions met with at great depths below the ſurface; not to mention that Holland looks to be an entire conqueſt upon the ſea, and, in a manner reſcued from its fury. Nevertheleſs, leaving aſide any arbitrary notions, we deduce, that a dereliction on one ſhore, is compenſated by encroachments on another; and judge it a neceſſary ordination of Providence, that there ſhould be an equal diſtribution of land and water for the proper circumſtances of the globe.

The firſt eſtabliſhed fact relating to the tranſmutation of water into earth, by the functions of vegetables, was advanced by Van Helmont, about the cloſe of the ſixteenth century, and he reſts his authority on the following ſimple experiment. He prepared a quantity of dried earth, and put it into an earthen veſſel, after moiſtening the earth with pure rain-water, he planted the trunk of a young willow therein, which, in the courſe of a few years, had acquired an amazing increaſe in weight; but, we are told, the earth was regularly ſupplied with either rain or diſtilled water: wherefore vegetables, he inſiſts, derive their immediate ſupport from the pure element alone. However, this Woodward warmly rejects, knowing water to impart much leſs nouriſhment, in proportion as it is purified by diſtillation; for a plant is ſaid not to grow ſo rapidly in diſtilled, as in ordinary water; and, by repeated diſtillation of the ſame, the plant will ſcarce flouriſh at all: Water, therefore, as ſuch, can only be regarded as the vehicle of earthy particles, with which it is impregnated, rather than an increaſer of them by its own bulk. Neither Helmont, nor Woodward, was perhaps ſufficiently aware how ſmall a portion of terreous matter vegetables in common give out, by conſuming to aſhes; ſtill granting, the increment of earth bears a coincidence with the growth. A manufacturer in pot-aſh procured out of 106 pounds, avoirdupoiſe weight, of dry, pealed oak, only 19 ounces of aſhes. The Biſhop of Landaff dried in the ſun a freſh pumkin, weighing 200 ounces; in nine days it loſt 190 ounces: the remaining 10 ounces afterwards, on being reduced to cinders, did not yield one ounce of earth.

M. Parmentier experienced, on diſtilling potatoes in a retort, that they afforded abundance of water; and one pound of the ſame root left behind ſcarce 36 grains of earthy reſiduum. There is no ſubſtance from which water cannot be divorced, even the drieſt; nay, the hardeſt ſtones contain a plenteous ſtock of it. Dr. Boerhaave preſerved hartſhorn forty years; when it turned as hard as any metal, ſo that, upon colliſion, ſparks of fire enſued, yet, by diſtillation in a glaſs veſſel, it produced one-eighth part of water. In fine, this element diffuſes itſelf univerſally, and is preſent in all ſpace where there is matter, fire and air not excepted.

In the Berlin Memoirs, for the year 1746, there is mention of Eller's obtaining earth from water, by ſimple trituration, in a glaſs mortar. And Wallerius, in 1760, by conducting the proceſs in veſſels of iron and bronze, procured, in a couple of hours, half a dram of earth out of one dram of diſtilled-water. Margraaf pleads its exiſtence, by varying the experiment. He put two ounces of diſtilled-water into a glaſs veſſel, ten inches high, and one or two inches in diameter, and cloſed the mouth with a ſmooth glaſs ſtopper; after the water had been ſhook in the tube eight days, it grew turbid; and, by continuing the agitation ſome time longer, he diſtinctly perceived, eſpecially upon expoſing the tube to the rays of the ſun, particles of earth in the water.

The opinions delivered in behalf of the convertibility of water into earth, by means of diſtillation, reſt upon a better foundation, and were canvaſſed with every avidity by philoſophers of high reputation. If Borrichius had the lead in ſuch experiments, the honourable Mr. Boyle was, properly ſpeaking, the firſt who paid a peculiar attention to the ſubject.

By reiterated diſtillation of water, he detected a layer of white earth adhering to the bottom of the alembic; and which, with the former writer, he is ready to impute to the tranſmutability of the water into earth, rather than to any extraneous impurity. Beſides, he expoſed diſtilled rain-water in a veſſel, hermetically ſealed, to a digeſtive heat, above a year; and, after it had remained awhile, ſmall concretions formed: and the longer the glaſs ſtood in the furnace, the more productive of earth: an event not ſo eaſy to explain, on the ſuppoſition of duſt floating in the atmoſphere, as, in this inſtance, the minuteſt atom of earth was refuſed admiſſion to the water. A friend of his, too, having poured a quantity of diſtilled rain-water into a clean, glaſs retort, and allowing it to ſtand in a digeſtive furnace, until the water totally diſſipated, the bottom of the veſſel was wholly covered with a whitiſh, inſipid earth. And he informs us of a phyſician, of indiſputable veracity, who procured from one ounce of water, diſtilled near 200 times, three-fourths of earth, which increaſed in proportion to the number of diſtillations.

Although Mr. Boyle profeſſes himſelf an advocate for the doctrine, he ever diſplays a commendable diffidence on the occaſion, and terms the hypotheſis a bold conjecture. Says he, " It were fit to know whether the glaſs body, wherein all the diſtillations are made, do loſe of its weight any thing near ſo much as the obtained powder amounts to." And again—"I could wiſh that it were demonſtratively determined, what is, on all hands, taken for granted, that diſtilled rain-water is a perfect, homogeneous body."

Margraaf, from a deſire of obviating theſe ſcruples, contrived a retort and receiver, made out of one piece of glaſs, and, through a perforation in the receiver, which was afterwards cloſed with a glaſs ſtopple, he poured an ounce of water, which had been carefully diſtilled thirteen times; this water he re-diſtilled thirty times more, without ſuffering any air to eſcape into the retort; when he obſerved that the water became more turbid after each ſeparate diſtillation, by the admixture of a pure, white earth: and the veſſels in which he performed theſe experiments were, as far as microſcopes could inſtruct him, as perfectly bright as when new; ſo that they might have contained the marine acid for years, without injury. This earthy matter Margraaf reports to be entirely different from the ſediment occaſioned by duſt; it being of a white colour, ſomewhat calcareous, and rather compoſed of little, ſparkling ſcales, as if cryſtallized.

Ten months elapſed before Mr. Godfrey ſaw any change in the conſiſtence of the water, and fifteen months 'ere its converſion into earth was completed. Finally, the Biſhop of Landaff[*] aſſures us, that, by diſtilling water ſlowly in a ſilver retort, and afterwards evaporating it on a poliſhed, ſilver plate, there remained a ſmall pellicle of earth. Several of theſe facts, however, have been called in queſtion, if not utterly ſubverted, by Boerhaave, Prieſtly, Lavoiſier, Black, and others. If water could be had alone, argues the former, it would poſſeſs all the requiſites of an element; be incapable of decompoſition, and as ſimple as fire; ſo, with whatever ſubſtances it is combined, when ſet apart from theſe, and ſufficiently purified: and alſo when diſtilled ſingly, or mixed with other matters, its nature and eſſential properties ſtill continue unalterable; but there is no expedient hitherto diſcovered for obtaining it ſo pure. He is convinced, no perſon ever found it in this ſtate; and the utmoſt of its purity only amounts to its being free from this or that ſort of admixture. Under the article Earth he writes thus.

"That afforded by the diſtillation of water, appears to come out of the air, into which it is raiſed along with the ſmoke, and numerous other parts of vegetable and animal bodies, which fly off in effluvia; for, though this earth be of itſelf ſo fixed, yet it is readily rendered volatile by fire, when mixed with lighter or viſcid bodies. Perhaps, alſo, in Mr. Boyle's method of procuring it by repeated diſtillation of fair water, which every time leaves a quantity of it upon the ſides of the retort employed in the operation, part of it may proceed from the cement of the glaſſes, or the duſt of the air, which comes in contact with the ſurface of the water, whilſt it is poured out of one veſſel into another."

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[*] Chemical Eſſays.

Furthermore adds he, "It ſhould be conſidered, that water can never be removed, or poured into any veſſel, without the mixture of ſome duſt therewith; ſo neither can the luting of the veſſel be diſtilled without loſing ſomething every time; I ſhould rather conclude, therefore, that the water, thus often diſtilled, acquired ſtill new earth from the duſt continually floating in the air. This duſt appears very ſenſible in a dark place; when, after we have ſtaid awhile without any motion, or the leaſt wind to raiſe it, upon admitting a ray or two of the ſun through a little aperture, we ſhall perceive the air ſwarm with legions of floating particles of duſt *." The ſame author, after diſtilling water over a gentle fire, for the ſpace of four months, affirms, it was perfectly pure; but leaving it to reſt in veſſels well corked, it ſhewed a ſlender kind of weedy matter, not unlike the ſtamina of plants; yet Schottus, who ſaw water in Kircher's muſeum, which had been preſerved in a veſſel, hermetically ſealed, upwards of fifty years, alledges, it was ſtill tranſparent and pure, and ſtood to the ſame height in the veſſel as at firſt, without the leaſt given to ſediment.

The ever-memorable Dr. Prieſtley, (who is not leſs conſpicuous for integrity, and liberality of ſentiment, than for his literary labours, exerciſed for the public good, but to whoſe inventive genius the philoſophic world is peculiarly beholden) inſtituted a train of experiments on water, put into glaſs tubes, ſealed up, and expoſed to a durable heat, with an intention of confirming the theory under conſideration; inaſmuch as he failed of ſucceſs, doubts whether his diſappointment might not have ariſen from the violence of heat uſed; and both Dr. Hill and Mr. Woolfe conceive that the heat ought to be very moderate, and long continued, before the wiſhed-for effect can well happen.

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* Boerhaave's Chemiſtry.

M. Lavoſier proſecuted this ſubject at ſome length, and did, what is amazing, no one elſe ever attempted; when reflecting the ſuggeſtion had been thrown out above a century ago by the Hon. Mr. Boyle: he ſimply weighed the glaſs veſſel after the operation, when it proved to be lighter than before; and this he aſcribes to the ſolution of parts of the glaſs; though, at the ſame time, is ſenſible of having procured three grains of earth, over and above the loſs of weight ſuſtained by his veſſel. And, indeed, Margraaf, on the other ſide of the queſtion, obtained but nine or ten grains of pure rain-water by twelve diſtillations.

Without meaning at all to decide on theſe arguments, I may be juſt allowed to hint, that glaſs is more deſtructible than ſome are aware of; for, by laying any while in earth, and examined with a lens, the ſuperficies is unequal from its abraſion.

The very accurate, and ingenious Dr. Black, boiled water for a month in a Florentine flaſk, with another inverted into its mouth, ſo as to exclude the ſurrounding air. It's appearance, at the cloſe, was ſuch as Mr. Boyle deſcribed; at firſt the water got muddy, and a white powder precipitated to the bottom; but, upon ſhaking the veſſel, and placing it in the ſun, the light was reflected into coloured rays. Hence he infers, that this ſubſtance was nothing more than thin ſcales of glaſs, detached from the veſſel by the undulation of the water, when they would very naturally decompound the ſolar light.

With this I diſmiſs the chief of the experiments adduced for, and againſt tranſmutation: thoſe in ſupport of it are perhaps calculated, quoting an expreſſion of the great Verulam, rather to allure, than extort conſent.

II. Conglaciation of Water.

THIS is a theme embarraſſed with every ſeeming difficulty, and on which many diſtinguiſhed philoſophers have indulged a paſſion for rhetorical conjecture; nor need I ſubjoin, is the diverſity of opinion yet thoroughly reconciled: thence it is Thomſon the poet aſks—"What art thou Froſt? and whence are thy keen ſtores derived, thou ſecret, all-invading power!"

The conſequences, reſulting from the mutation of temperature in bodies, conſtitute a ſource of highly-intereſting information: no facts are in themſelves more curious, or promiſe a greater inſight into the myſteries of heat, than ſuch as accompany the converſion of a fluid into a ſolid, by congelation.

I would here premiſe, as an eſtabliſhed poſition, that the reſpective conditions, ſo ſuſceptible to all bodies, are attributed to the temperature of the places under which they exiſt: add to this, the preſſure of the ſuperincumbent atmoſphere. Hence, could we for a moment ſuppoſe the terraqueous world approached ſo near the influence of the ſolar rays, as however, happily for us, no portion of the earth is obnoxious to, the ſolid parts would, more or leſs, put on the form of vapor. On the contrary, were the diminution of heat to go beyond the bounds aſcribed to it, not only water, but, poſſibly, all the aeriform fluids, might be deprived of elaſticity, transform into a heavy, confuſed maſs, and the immenſe buſineſs of the creation become a lifeleſs, torbid, and diſmal ruin. One clear and very obvious truth then is, that no body can aſſume an aerial, or even a liquid ſtate, without it is from fire: ſo, with M. Amontons, we gather, that the air itſelf, in ſo far as it is elaſtic, differs only from other ſubſtances in being incomparably more volatile, and, therefore, cannot take any other ſhape, ſo long as the conſtitution of the world goes on the ſame; yet might be condenſed into a ſolid, in all human probability, by the mere diminution of heat *.

We proceed, then, to conſider heat as having a poſitive quality, whilſt cold is a more negative power. This, however, is contradicted by ſome, from an appeal to their feelings, that a lump of ice,

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* Dr. Crawford has fully evinced, that the atmoſpherical air, from having more fire than any other body, is ſo retentive of its fluidity; and he ſuppoſes it to contain 100,000 times as much fire as red-hot iron does.

ice, by producing an uneaſy ſenſation in the hand, has as diſtinct a feel as a hot body. But, ſince this ſenſe varies in its notices, according to the temperature of the human body, ſuch deductions are, at beſt, but ill-grounded. For example, during the autumn, at the time the winter is about ſetting in, numbers think the weather exceedingly cold; when, again, the perceptions of others are very little affected: but theſe differences conſiſt only in the relative heat or cold of the body of the obſerver, with reſpect to the ſurrounding air. Further, if we take a quantity of water, lowered down to ſuch a temperature, as ſhall ſeem warm to one perſon, cold to another, and neither warm nor cold to a third; it is only expedient for the firſt to immerſe his hand in cold water immediately before; the ſecond to endure ſomewhat of a feveriſh heat; and the third to enjoy a natural ſtate.

Nay, more, it can be made to appear warm, if felt, with one hand, and cold to the other; ſo that, evidently, our ſenſations of heat and cold depend on a certain difference of temperature between theſe bodies and our organs; and not upon any different qualities in the bodies themſelves.

The celebrated Dr. Cullen ingeniouſly attempts an elucidation of the operation of cold on the living ſyſtem; and which, from being truly philoſophical, I am induced to deliver in his own words [*],

"The power of cold may be conſidered as abſolute or relative.

"The abſolute power, is that by which it can diminiſh the temperature of the body to which it is applied. And thus, if the natural temperature of the human body is, as we ſuppoſe it to be, that of 9° of Farenheit's thermometer, every degree of temperature leſs than that, may be conſidered as cold, with reſpect to the human body; and, in proportion to its degree, will have a tendency to diminiſh the temperature of the body, But, as the living, human body has in itſelf a power of generating heat, ſo it can ſuſtain its own proper heat to the degree above-mentioned, though ſurrounded by air, or other bodies of a lower temperature than itſelf [†]: and it appears from obſervation,

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[*] Firſt Lines, vol. I.

[†] Dr. Cullen, long ago, ſuggeſted many arguments to ſhew that living animals have a power of generating heat, independently of any common, chemical, or mechanical means, either of friction or fermentation; and alſo of generating cold, or deſtroying heat, when the heat of the atmoſphere exceeded the proper temperature of their bodies. This power, however it acts,

vation, that, in this climate, air, or other bodies, applied to the living man, do not diminiſh the tem-

acts, ſeems to attend life very univerſally. Mr. Hunter found a carp preſerve a coat of fluid water round him, long after all the other water in the veſſel had been congealed by a freezing mixture; and he has alſo ſhewn that vegetables poſſeſs ſome degree of this generating heat. The ſudden melting of ſnow on graſs, whilſt that on gravel walks continues unthawed, and many other ſimilar phenomena, can be adequately explained only on this principle. Dr. Solander ſtood in a room heated to 210 deg. for three minutes; and Sir Joſeph Banks remained ſeven minutes in the heat of 211 deg. The heat of their bodies, in theſe ſeveral experiments, roſe very little above its uſual ſtate. Whenever they breathed on the thermometer, the mercury ſunk ſeveral degrees; every expiration afforded a pleaſant, cooling impreſſion to the noſtrils, and their cold breath cooled their fingers. Dr. Blagden, who was likewiſe preſent, on touching his ſide, found that it felt like a corpſe, tho' the actual heat of his body was 98 deg. In ſubſequent experiments the heat of the room was raiſed to 240 deg. and ſometimes to 260 deg.: theſe exceſſive heats were borne for a conſiderable time, with little inconvenience by the gentlemen who expoſed themſelves to them, both naked, and with their cloaths on: nor was the heat of Dr. Blagden's body at all increaſed, though the velocity of his pulſe was, in one inſtance, more than doubled. In the ſame, heated air, which they breathed, eggs were roaſted quite hard in 20 minutes; and beef-ſteaks were dreſſed in 33 minutes; and, by blowing on them, in 13 minutes. A blaſt of the heated air, from a pair of bellows, was ſcarcely to be endured, for the following obvious reaſon: When the ſame air remained for any time in contact with the body, part of it's heat was de-ſtroyed;

temperature of his body, unleſs the temperature of the bodies applied be below 62°. From hence it appears, that the abſolute power of cold, in this climate, does not act upon the living, human body, unleſs the cold applied be below the degree juſt now mentioned. It appears alſo, that the human body's being ſurrounded by air of a lower temperature than itſelf, is neceſſary to its being retained in it's proper temperature of 98°: for, in this climate, every temperature of the air above 62°, applied to the human body, though ſtill of a lower temperature than itſelf, is found to increaſe the heat of it. And from all this it appears, that the abſolute power of cold, with reſpect to the human body, is very different from what it is with reſpect to inanimate bodies.

"The relative power of cold, with reſpect to the living, human body, is that power, by which it produces a ſenſation of cold in it; and, with reſpect to this, it is agreeable to the general principles of ſenſation, that the ſenſation produced is not in proportion to the abſolute force of im-

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ſtroyed; and, conſequently, the body was ſurrounded with a colder medium than the air of the room; whereas, when freſh portions of the air were applied to the body in ſuch a quick manner, that no part of it could remain in contact a ſufficient time to be cooled, the heat muſt be ſenſibly greater.

preſſion, but according as the new impreſſion is ſtronger and weaker than that which had been applied immediately before. Accordingly, with reſpect to temperature, the ſenſation produced by any degree of this, depends upon the temperature to which the body has been immediately before expoſed; ſo that, whatever is higher than this, feels warm, and whatever is lower than it, feels cold; and it will therefore happen that the oppoſite ſenſations of heat and cold may, on different occaſions, ariſe from the ſame temperature, or be marked by the thermometer. With reſpect to this, however, it is to be obſerved, that though every change of temperature gives a ſenſation of cold or heat, as it is lower or higher than the temperature applied immediately before, the ſenſation produced is, in different caſes, of different duration. If the temperature, at any time applied, is under 62°, every increaſe of temperature applied will give a ſenſation of heat; but, if the increaſe of temperature does not ariſe to 62°, the ſenſation produced will continue long, but be ſoon changed to a ſenſation of cold. In like manner, every temperature, applied to the human body, lower than that of the body itſelf, gives a ſenſation of cold; but if the temperature applied does not go below 62°, the ſenſation of cold will not continue long, but be ſoon changed to a ſenſation of heat."

Hence the organs of the human frame are not only imperfect, when employed to meaſure the temperature of bodies, but, likewiſe, too confined, in every inſtance; and, therefore, temperature is more properly uſed to denote any degree of heat or cold, whether within the limits of our perceptions, or not; and is appreciated by the obſervation of its effects on bodies.

Congelation is another circumſtance which induced many philoſophers of eminence to imagine, that cold had, like heat, poſitive exiſtence; and, from being accuſtomed to ſee water in it's ordinary ſtate, they deemed liquidity as natural to it; hence conceiving no bodies are abſolutely fixed, but only relatively ſo, with reſpect to our fires. Others, again, who, with equal confidence, deny water's univerſality, are loath to admit that any is afforded us by nature; for what gives itſelf the form, ſay they, can be called nothing elſe than a real fuſion: ſo, according to the younger Lemery, Ice is, properly ſpeaking, the re-eſtabliſhment of the parts of water to their primeval ſtate. Controverſies of this kind, however, allow of no deciſion; ſince we ſhould inform ourſelves of what human inveſtigation never will attain; and that is, whether heat or cold firſt commenced their operations upon nature? If, in our climate, liquid water uſually obtains, there are many other places of the world wherein it is more generally ſolid: ſo either ſuppoſition, taken abſtractedly, leads to error. The Moſaic writings, indeed, ſhew ſtrong motives for affirming, that earth and water were created together, and that the latter was in a liquid ſtate even before the formation of the ſun; conſequently poſſeſſed, at leaſt, 32 degrees of our thermometrical degree; nor could the earth be void of incaleſcence, otherwiſe the water muſt have ſpeedily congealed. The globe, then, we infer, from *its* very beginning, occupied the heat neceſſary for the purpoſes it was intended to ſerve; and, moreover, this ſame heat, probably, might have ſuffered an entire annihilation, were it not preſerved and renovated by the inceſſant power of the ſun, to which one half of the earth's ſurface is conſtantly expoſed. Yet, as ſeveral phyſical cauſes conſtantly intercept the activity of the ſolar rays in theſe and other regions, the neceſſity of recurring to ſome adventitious reſource ſtill remained. Agreeable to Dr. Martin, M. de Mairan, and others, the rigor of the winter's cold is tempered by the heat imparted to the atmoſphere from the earth itſelf; and to this they beſtow the appellation, in common with ſome philoſophers of the day, of a central emanation; through an apprehenſion that there exiſts, in the center of the earth, a huge maſs of fire. We could offer ſeveral objections againſt ſuch an hypotheſis; and one, in particular, occurs to us, which is, that the heat of the earth does not increaſe as we deſcend to it, but, at the greateſt depths, is nearly the ſame as the mean, annual temperature of the latitude. For example, in the mine of Joachimſtahd, in Bohemia, though reputed one of the deepeſt now extant, M. Monnet found the temperature, at the depth of 1700 feet, to be only 50 degrees. It may here be aſked, how is this degree of heat maintained at ſo great a depth below the ſurface, without any immediate communication with the ſun, and atmoſphere of the earth? I would reply, that the regular degree of heat, obſervable in the internal parts of the earth, is likely enough derived from the heat of our water ſinking in, whoſe temperature, as Mr. Hellant firſt remarked, borders on an arithmetical mean of the two extremes of ſummer and winter; and varies very little in the different periods of the year. All the heat, therefore, diſperſed over the globe, it is but reaſonable to conclude, originates with the ſun; and as to cold, in a more enlarged ſenſe, we need chiefly account for it in no better way, than by the ſun's deceſſion, or winds blowing from ſituations leaſt expoſed to its influence *. So on the one hand, at the equator, where the ſun-beams dart directly perpendicular,

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* The great cold in Europe is attributed to the following cauſes :

1ſt. Univerſal cold in the preceding ſummer. For, as the winter's heat is very much derived from the earth, if this be deprived of its uſual ſtore of heat, the want of it muſt be perceived the enſuing winter.

2dly. Heavy rains, followed by eaſterly or northerly winds: a ſource of great cold, in any ſeaſon, owing to the powerful evaporation promoted by theſe dry winds.

3dly. Weſterly or ſoutherly currents, in the upper regions of the atmoſphere, while eaſterly or northerly prevail in the lower. For the warm currents are in great meaſure deprived of their moiſture by the cold of the ſuperior regions; and this, deſcending in the form of ſnow, cools the inferior ſtrata below their uſual temperature.

4thly. The arrival of Siberian or American winds. Siberia, though 2,800 miles to the eaſt of London, yet, Mr. Smeaton computes that a common high wind moves at the rate of 35 miles an hour, hence may paſs to us in three days from Siberia. Now Dr. Blagden has proved, that a current of 20 leagues in breadth, and 10 degrees warmer than the ocean through which it flows, may preſerve four degrees of its heat, after having traverſed a ſpace of 7 or 800 miles: and Sir Benjamin Thomſon has ſince aſcertained, that air is a much worſe conductor of heat than water; therefore, we may well ſuppoſe that the Siberian winds can preſerve much of their original temperature on arriving cular, the clime is almoſt inſupportable to any living mortal; and many of its inhabitants are occaſionally compelled to repoſe themſelves in ciſterns of cold water, from the ſcorching heat: whilſt, in the Frigid Zone, the people are as much incommoded by the ſun's abſence, as, in the former inſtance, they were by its proximity; and, in confirmation of this, I ſhall here notice certain low degrees of heat, of which we can form no conception.

A remarkable relation of the ſort we have in the hiſtory of a journey to the north end of the Baltic, by the French academicians, who advanced within the polar circle, in order to make obſervations with regard to the important queſtion concerning the figure of the earth. In this forlorn tract, they were neceſſitated to employ all their attention in preſerving themſelves from the cold of the ſeaſon; living in rooms heated

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ing here; particularly if they blow with conſiderable force, and laſt ſome days.

5thly. The fall of a ſuperior ſtratum of the atmoſphere. This happens when a cold wind, in the upper regions of the atmoſphere, paſſes over a country, the lower ſtrata of whoſe atmoſphere are ſpecifically lighter; and hence a low ſtate of the barometer generally precedes ſuch an extraordinary cold.——*Kirwan's Eſtimate of the Temperature of different Latitudes.*

heated with ſtoves; and, upon opening their windows, the external air ruſhing in, froze their breath into whirls of ſnow. Such dreadful cold made the ſpirit of wine congeal in the thermometer; and the ſcale fell to 63 degrees below froſt.

The country of Greenland wears an eternal covering of ſnow and ice; the air there is intolerably cold, being either refrigerated with froſts, or diſturbed by tempeſts; and in ſuch places only, in winter, when the ſun is enjoyed for an hour or two a-day, the cold can be endured: but, where the ſun is entirely below the horizon, whilſt company are drinking tea, the emptied cup, when put down, will freeze to the table *. Paul Egede, in his Journal of January, 1738, ſays, that in latitude of 68 deg. the ice and hoar-froſt reached through the chimney to the ſtove's mouth, without being thawed by the fire, even in the day time. The doors and walls of his room were as if plaiſtered over with ice; and, what is ſcarcely credible, the linen froze in the drawers; the beds were frozen to the bedſteads; and the eider-down coverlid and pillows became quite ſtiff with froſt, an inch thick, from the condenſation of the breath.

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* Crantz's Deſcription of Greenland.

And further, they were obliged to hew their fleſh-barrels in pieces, to get out the meat, which, when put over the fire, the outſide appeared ſufficiently boiled, before the inſide was hardly thawed.

Captain Ellis ſpeaks of the northern parts of America, round Hudſon's-Bay, viſited by him in 1746 and 1747, as intenſely cold during the winter he reſided there; in ſo far, that if his people touched iron, or any ſmooth, ſolid ſubſtance, their fingers adhered to it. And, upon drinking a glaſs of brandy, if the lips or tongue came in contact with the glaſs, part of the ſkin froze to it. Moreover, by digging a hole in the earth, 12 feet deep, to ſtow their liquor in, a frozen ſoil even preſented itſelf at that depth.

Dr. King, who paſſed 11 years in Ruſſia, remarks, that the cold at St. Peterſburgh, in the months of December, January, and February, is often from eight to 15 or 20 degrees below nought: and when the thermometer ſtood at 25 degrees below nought, boiling water, thrown up into the air by an engine, ſo as to ſpread, has fallen down in a perfectly congealed ſtate. There, in ſevere winters, ſparrows, though a hardy ſpecies of birds, have been ſeen quite numbed, and unable to fly, by the cold: and drivers, when ſitting on their loaded carriages, are ſometimes frozen to death in that poſture. The extinction of vegetable life is, too, not unfrequent; for the expanding power of the ſap, in the article of freezing, is ſo conſiderable, as to burſt trees aſunder, with a dreadful exploſion, not inferior to the diſcharge of ordnance. But, in the year 1740, this happened in the ſouth of England, when the thermometer ſtood one below nought.

Both Siberia and Iceland ſupply enormous cold; the former lying in the center of the great continent of Europe and Aſia, is expoſed to more violent degrees of it than any other country we know of. Baron Demidoff there obſerved the mercury to ſink down to 10 deg. under Zero; which is farther below the point of congelation, than the heat of boiling-water is above it. This, however, was thought ſevere, even by the natives, as ſeveral wild beaſts fell a ſacrifice to it, and profeſſor Gmelin could only ſtand a few minutes out of doors.

Returning from this digreſſion, if ſuch it can ſtrictly be deemed, it is to our purpoſe next to take into conſideration other cauſes of cold, whether natural or artificial, than thoſe yet ſpoken of.

Evaporation, in whatever way induced, furniſhes a powerful ſource of cold: were it not ſo in the equatorial regions, life could not probably ſubſiſt; hence, by a wiſe allotment of nature, the ocean, in ſome meaſure, conſtantly preſerves this form; and vegetables not only refreſh animals by their ſhade, but likewiſe diffuſe a degree of cold by the perſpiration from their ſurface; and which explains to us, why in America, countries under the ſame parallel of latitude, nay, under the ſame hemiſphere, are of different temperatures.

Somewhat upon the like principle the blacks at Senegambia cool their water. They fill tanned leather bags with it, and ſuſpend them in the ſun; the liquid oozes more or leſs through the leather, ſo as to keep the outward ſurface of it wet, whilſt, by its rapid and continued evaporation, the contained water grows wonderfully cooler *. In Spain they have a porous, earthen jar, called Buxaros, whoſe outſide is moiſtened by the water filtering through; and, from the increaſed perſpiration, upon expoſure to the ſun, the liquid becomes as cold as ice †.

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* Philoſophical Tranſactions, 1780.

† Swinburne's Travels.

After the ſame manner, the ingenious proceſs for obtaining ice in the Eaſt-Indies, is to be explained; and which we have particularly deſcribed by Sir Robert Barker *, who, during his travels in that country, never ſaw any natural ice, ſince the thermometer ſeldom falls there near ſo low as the freezing point. The inhabitants, therefore, have recourſe to art, to effect the congelation of water. For this intention, they dig, on a large, open plain, three or four pits, about thirty feet ſquare, and two feet deep each; the bottom of which they cover, about eight inches thick, with the fibrous ſtems of the large Indian corn, or thoſe of the ſugar cane, after the juice is expreſſed: upon this they ſet, in rows, a number of ſmall, ſhallow, unglazed, earthen pans, of a quarter of an inch thick, and, perhaps, one inch and a quarter deep, which are formed of ſo porous an earth, that the water penetrates through the whole ſubſtance. Theſe veſſels are filled, towards the duſk of the evening, with ſoft, boiled water; and, if left in that ſtate over night, a congelation takes place on the ſurface; but this, more or leſs, according to the temperature of the weather: there being more formed in dry and warm, than in cloudy, weather; although the latter may chance to be colder to

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* Phil, Tranſ. vol. lxv. p. 2.

the feel of the human body. The ice-makers, in the morning, early, before ſun-riſe, attend at the pits, and collect, what was frozen, in baſkets, in order to be conveyed to the place of preſervation. This is generally prepared in ſome high, dry ſituation, by ſinking a pit, fourteen or fifteen feet deep, lining it firſt with ſtraw, and then with a coarſe kind of blanketing; the ice is depoſited in the pit, and beat down with rammers, till, at length, its own accumulated cold again freezes it into a ſolid maſs: the mouth of the pit is well ſecured from the exterior air, with ſtraw, and a covering of wool; and a thatched roof is thrown over the whole. The aſpect of ice-houſes ſhould be towards the eaſt, or ſouth-eaſt, for the advantage of the morning-ſun, to expel the damp air, as that is more pernicious than warmth; for which reaſon, trees growing in the vicinity, are improper. The beſt ſoil for an ice-houſe to be made in, is chalk, as it carries away the waſte water, without any artificial drain; and, next to that, a looſe, ſtony, or gravelly earth.

Every circumſtance diſpoſing to evaporation, in ſhort, increaſes the cold produced by it, as Dr. Black has well illuſtrated. He placed a tin veſſel, containing water, on an iron plate, heated by a fire underneath; the temperature of the water, when ſo ſituated, was about 50 deg.; in a few minutes, it roſe to 212 deg. and required 20 minutes more before ſt thoroughly diſſipated; but all the time, did not augment one ſingle degree in its heat: that, of courſe, the evaporation, in boiling, was productive of cold, by counteracting the heat continually pouring in from the iron.

Mr. Wilſon, Profeſſor of Aſtronomy at Glaſgow, remarked, that when the bulb of a thermometer was ſet upon the ſurface of ſnow, it fell 10 deg. or 12 deg. lower than when the ſame was placed in the open air; but whether this was owing to the evaporation going on, I dare not poſitively determine, For the preſent, we ſhould avail ourſelves of many important facts, appertaining to volatile fluids, ſtarted by Dr. Cullen *; as alſo, others of a ſimilar ſort, by Meſſrs. Richman, Mairan, and Beaume†. Suffice it here only to ſay, that theſe reſpectable philoſophers have demonſtrated,

Firſt, that when a thermometer is immerſed into any evaporable fluid, upon being abruptly withdrawn, it falls ſeveral degrees, and again aſcends, inſenſibly, no ſooner than the fluid is evaporated, till having recovered the exact temperature of the air, and ſurrounding bodies in general.

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[*] Edin. Phy. Eſſ. vol. iii.

[†] Lavoiſier's Eſſays.

Secondly, as the degree of cold acquired, is in proportion to the evaporability of the fluid, ſo the deſcent of the thermometer is leſs quick, and does not extend ſo far as when the bulb is moiſtened with water, as by ſpirit of wine, volatile alkali, or more eſpecially ether; and, upon repeating the experiment with the latter, as faſt as the thermometer becomes dry, the cold increaſes, more and more, becauſe the efficient cauſe is hereby continued.

Thirdly, If the evaporation is accelerated by any other means than that of heat, the intenſion of cold will be proportionable; ſo that, not only all evaporation is attended with cold, but even the propagation of cold is governed by a certain law correſpondent to the rapidity of the evaporation. And the celerity with which water, of a definite temperature, evaporates, is influenced partly by the degree of heat prevailing in the atmoſphere; partly, by the wind blowing upon the thermometer; partly, by the dryneſs, or humidity of the air; and by other cauſes.

Laſtly. They have proved that evaporation, under an exhauſted receiver, will occaſion more cold than when directly expoſed to the atmoſphere; and vitriolic ether, the moſt volatile fluid in nature, when placed in ſuch a ſituation, ſunk the thermometer 48 deg. below Zero: a degree of cold adequate to the freezing of water in the hotteſt day of ſummer.

There are experiments, in which, by certain combinations of ſalts and water, a ſudden degree of cold is produced, far below what either of theſe ſubſtances were ſuſceptible of when apart: from hence, philoſophers ſuppoſed coldneſs to ariſe, with ſome extraneous ſaline atoms conveyed by the air, and uniting with the water contributed to its congelation. The Corpuſcularian ſchool gladly embraced this notion, but on no ſolid foundation; for, it will hereafter come to be proved, that the cold introduced is, in conſequence of peculiar modifications of heat, and not owing to the interpoſition of frigorific particles, or their operation as ſuch upon water *.

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* There is, neverthele*ſ*s, a circumſtance mentioned, which could we but give implicit credit to, would go ſome length towards evincing the reality of this latter, in a few places of the world. It is remarked, by a very late writer, that the temperature of the air, in the province of Pe-tcheli, noways accords with the latitude, as all the rivers there are, during four months of the year, ſo much frozen, as to allow of horſes, and waggons of heavy burthen, to paſs over with ſafety; but, what appears ſtrange, the whole body of ice is formed in one day; and yet

On ſaturating equal portions of water with ſal ammoniac, with nitre, with marine-ſalt, the former ſunk the mercury 26 deg[*]. the ſecond, 6 deg. and

yet, in ſuch ſevere froſt, we learn, one does not feel that ſharp and pinching cold known to Europeans. The preſence of nitre is given as a phyſical explanation of theſe phenomena, ſince not only the earth and ſoil abound with this ſalt, but whole fields, in the neighbourhood of Peking, are covered with it; and every morning, at ſun-riſe, the country, in certain cantons, is as white, as if ſprinkled by a gentle fall of ſnow. The facility with which water freezes here, the ſolidity of the ice, and its duration, truly excite one's aſtoniſhment. Father Amiot, at Peking, filled a tub with water, placed near one of Reaumur's thermometers; the ſurface was immediately congealed, when the mercury ſtood only one degree above the freezing point; but when it ſtood three degrees below froſt, the water became one ſolid maſs of ice, provided the diameter of the veſſel did not exceed a foot and a half, and the depth of the water, four or five inches. This water, when the weather was fine, continued in the ſame ſtate of congelation, as long as the mercury in the thermometer, did not riſe higher than three degrees above nought; when the mercury roſe higher, it then began to diſſolve, but ſo ſlowly, that two or three days were ſcarcely ſufficient to reſtore it to its liquid ſtate.

Abbe Grocier's Deſcription of China, vol. i.

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[*] In every inſtance wherein I ſhall have occaſion to ſpeak of degrees of heat or cold, I confine myſelf to Fahrenheit's ſcale; and the expreſſion of higher, or lower, will always be according to that ſcale.

the latter only 2 deg.; the mineral alkali, and nitrous acid, 22 deg. A mixture of ice or ſnow, and ſal ammoniac, pointed at Zero. Three ounces of equal parts of ſal ammoniac, and nitre, pulverized, and mixed together, were added to four ounces of pump-water, at 50 deg.; the ſolution, after ſtirring, had the temperature of 14 deg. and it ſoon froze ſome water, contained in a ſmall phial, when immerſed therein. The mixture was afterwards evaporated to dryneſs, for the purpoſe of recovering the ſalt, which being again powdered, was found not to have its quality of refrigeration in the leaſt impaired, as was more deciſively proved by many ſubſequent evaporations. The cold may be kept up by decanting off the clear ſolution, and adding freſh water, obſerving conſtantly to ſupply it with as much of the powder, as it will diſſolve. A mixture of equal parts of ſal ammoniac, and nitre, is ſufficient for freezing water, or cream, at Midſummer. Six drams weight of rain-water, with the ſame proportion of nitrous ammoniac in very fine powder, made the thermometer fall from 50 to 4 deg.; and, by the addition of a like quantity of mineral alkali, it ſunk 7 deg. lower: thus affording more cold, even in ſummer, than ſnow and ſalt do in winter. The following mixture, is very powerful: ſtrong, ſmoking, ſpirit of nitre, is diluted, with half its weight of water;

to three parts of this liquor, when cooled to the temperature of the air, four parts of Glauber's ſalt, in fine powder, are added: the mixture is well ſtirred, and immediately afterwards, three parts and a half of nitrous ammoniac are ſtirred in. Theſe appear to be the beſt proportions, when the temperature of the air, and ingredients, is 50 deg. but, at higher or lower temperatures, the quantity of diluted acid requires to be proportionably diminiſhed, or increaſed. This ſame mixture, ſunk the thermometer 52 deg. viz. from 32 above Zero to 20 below. The ſalts, however, ſhould be procured as dry and tranſparent as poſſible, and withal freſhly powdered *.

In a very moderate degree of heat, by the effuſion of ſtrong ſpirit of nitre upon ſnow, mercury congealed, which correſponds to 40 deg. below nought. But, by theſe means, the greateſt cold is eſtimated at 148 deg. below froſt; and, was the nitrous acid of due ſtrength, I need not heſitate to ſay, it might be carried yet farther: not but that the action of bodies, upon each other, is probably limited, their attraction ceaſing on a certain diminution of heat, and all poſſeſs a determinate degree, in this reſpect. So philoſophers endeavour to

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* Watſon's Eſſays. Walker's Experiments on the Production of Artificial Cold. Vid. Phil. Tranſ. 1788.

to fix a point at which no heat can be ſaid to be preſent; and a body, in ſuch a ſtate, M. Gadolin ſurmiſes, would ſink Farenheit's thermometer down to 1408 deg. but 1500 deg. in the loweſt point, agreeable to Dr. Crawford's calculations *.

The biſhop of Landaff is anxious to be informed, whether any given kind of ſalt in ſolution, ſupplies the ſame degree of cold, whatever temperature the water ſhould be of previouſly. From the reſult of his enquiries, we are ſatisfied, that the cold here derived, is in no ſenſe influenced by the temperature of the water; for, although the experiment was only tried by the learned prelate on ſal ammoniac, yet we may ſafely transfer the like reaſoning to either of the ſalts in queſtion. By uſing one mixture to cool the materials of a ſecond, and this again of the third, we lower the temperature conſiderably below froſt, and the poſſibility of freezing water, in the hotteſt ſeaſon, is rightly enough deduced from hence. The cold procured, being generated merely during the liquefaction, becomes very tranſient; as no ſooner than the ſalt is diſſolved, the mixture arrives at its utmoſt intenſity, and by the heat inceſſantly flowing in from the neighbouring bodies, the temperature gradually

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* Crawford, on Animal Heat.

approaches to that of the circumambient air; this, however, occurring, ſooner or later, as the compound ratio of the quantity and ſurface of liquid expoſed, is greater, or leſs.

It might ſeem extraordinary to us, that congelation does not invariably follow the reduction of temperature; and we can refrigerate water at leaſt 12 deg. below the freezing point, without deſtroying its liquid ſtate. The ingenious Dr. Blagden made a few novel experiments, with an expreſs deſign to inveſtigate the cauſe; but we have to lament, the ſubject is ſtill involved in much obſcurity. On expoſing ſeveral waters to the action of the common freezing mixtures of ſnow and ſalt, he found, that ſome diſtilled water, endured cooling as low, as near 22 deg. Diſtilled water, diveſted of air by ebullition, fell to 20 deg. one-third. Hard, pump-water, diſcovered this in a leſs eminent degree; and turbid water, of the new river, as well as pump-water, rendered turbid by the addition of a muddy ſediment, were ſcarcely lowered below 32 deg. without congealing.

When the bulbs of two thermometers were filled, one with rain, and the other with pump-water, and the water in each boiled till one-third only remained; neither of them could be made to freeze, till their temperature was lowered nearly to 5 deg. whether the tubes were open or ſealed; but unboiled water, in the ſame ſituation, froze in a higher temperature. This ſame property in water, Dr. Blagden aſcribes to its want of air, and its tranſparency; and accounts for common water freezing the more readily after boiling, from the precipitation of calcareous earth originally held in ſolution by ſixed air, giving a turbidneſs to the liquid. Even mercury, the mineral acids, and ſaline ſolutions in general, bore to be cooled below their reſpective, freezing points *.

The particles of water, in the act of congelation, have a tendency to arrange themſelves, by deſcribing certain angles; and, according to M. Mairan, the firſt maſſes are oblong, and ſharp-pointed, proceeding from the ſides of the veſſel towards the centre, while other chryſtals again ſhoot at their ſides in radii, always making off at the ſame preciſe angle of 60 deg. M. Romé de L' Iſle finds, by calculation, that the primitive form of ice is an equilateral octoedron; M. Haſſenfratz, a priſmatic hexaedron. But, later experiments of M. de Antic, ſeem to reconcile any difference of opinion, with Mairan's facts. This diſpoſition to a particular

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* Vide Blagden's Experiments. Phil. Tranſ. 1788.

mode of freezing, may depend on the more intimate compoſition of the water, ſuch as the arrangement, attractions, and form of its particles, which, perhaps, by a ſort of polarity, are inclined to run into methodical lines, inſtead of uniting ſimply together; and, by ſuch configuration of theſe needle-like parts, many inviſible interſtices obtain in the maſs, occaſioning it to occupy more ſpace. The freezing of water, in every inſtance, was univerſally underſtood to commence at the ſurface; but, of late, the validity of the concluſion, is rendered very doubtful. We rely on the teſtimony of individuals, who more immediately inhabit the ſhores. The nets of fiſhermen, M. Brauns recites, are frequently entangled by the ice at bottom, although no congelation on the ſurface; and, in the ſea, the ſame has occurred, at the depth of 17 fathom. And, on throwing iron nails, and other extraneous ſubſtances, into a tub-full of water in froſty weather, and kept flowing ſimilar to the current of a river, theſe bodies were imbedded with ice, whilſt the ſurface of the water diſcovered no froſt: yet, what is ſtrange, in another veſſel, under all circumſtances alike as the former, if excepting the want of agitation, the ſurface only froze, without any ice at bottom. Dr. Hales long ago remarked, in his vegetable ſtatics, that ice was never met with at the bottom of tranquil water, but he noticed it in that of ſtreams; and this phenomenon he explains, by ſaying, that the ſuperior parts of ſtagnant pools, are colder, in froſty weather, than the inferior; but, in rapid waters, the uppermoſt parts are mixed with the inferior ones, and the whole body of liquid is cooled nearly alike; and as the water flows quicker on the ſurface than below, it freezes ſooner in the latter. Whatever the cauſe is, the effects are ſingular and ſurpriſing.

Water, during its tranſition from a liquid to a ſolid, ſuddenly expands; and, philoſophers want to eſtimate the force of this expanſion. Mr. Boyle, confined a quantity of water, in a braſs tube, of three inches diameter, with the larger end of it properly cloſed, and with the upper end open, only having a plug drove into it; he then loaded it with 74 pound weight, whereby the water, in freezing, dilated ſo forcibly, as to lift up the weight. Huygens burſt an iron cannon, in the ſame way. But the Florentine academicians engaged in the neateſt experiment of all: they took a braſs globe, of about an inch thick, and after boring a little hole into it, had it filled with water; they ſet the globe, previouſly abſtracting ſomewhat from its bulk, upon a mixture of ſnow and ſalt, when, ſoon after, the ſides burſt aſunder; and Muſchenbrook, accnrately computes the force of the water's expanſion, equal to 27,720 pounds weight.

In cold climates, the ice is ſo firm, as to have been employed in the conſtruction of edifices; differing, however, from ſtone, by melting, in a much leſs degree of heat. At the fanciful marriage of Prince Gallitzen, in 1739, the Ruſſians built a houſe out of a large block of ice, conſiſting of two apartments, whoſe furniture, even to the nuptial bed, was of the ſame; and the icy cannons and mortars, fired in honor of the day, performed their office repeatedly without diſſolving *.

As Gallileo firſt perceived, ice is ſpecifically lighter than water, generally in the proportion of 8 to 9; ariſing from the quantity of air, interſperſed between its parts.

A ball of ice, thrown on hard ground, rebounds, as other ſolids; ſo, its elaſticity is greater than that of liquid water.

Laſtly, ice is ſubject to a conſtant diminution of bulk, owing to its abraſion, by the action of the

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* Manſtein's Memoirs of Ruſſia.

air; but, with Dr. Watſon, I eaſily conceive the loſs of weight any given quantity of ice ſuffers, in this way, in a given time, will depend partly upon its conſiſtence, partly upon the temperature of the atmoſphere, with reſpect to the degrees of cold and humidity, partly upon the velocity of the wind, and probable enough upon the agency of other cauſes with which we are leſs acquainted.

SECONDLY,

Water in a State of Liquidity †.

WE view heat as the grand inſtrument of liquidity, throughout the univerſe; and of which all matter poſſeſſes a determinate quantity; and, according to the degree of denſity, or coheſion, ſhews a capacity to abſorb more or leſs of. A body, therefore, on becoming liquid, contains more than when ſolid; and, to induce a vaporous ſtate, a ſtill greater portion is required.

Within the bounds of ſolidity, no variation, in this reſpect, has hitherto been diſcloſed; tho' we cannot doubt but, that the heat gradually augments, in proportion to the approximation to fluidity; and, vice verſa. Every particle of water, ſays Bergman ‖, by exerciſing a certain force of attraction, for this ſame principle, forms an atmoſphere, as it were, of its own. Whilſt theſe atmoſpheres oppoſe the particles from coming into contact, the whole remains liquid: when they are enlarged, the diſtances increaſe, and an expanſion ſucceeds, till, at length, the ſuperficial particles are reſolved, by the neceſſary portion of heat, into elaſtic vapor. On the other hand, the exceſs of heat being progreſſively leſſened by the coolneſs of the air, the bulk of the vapors is contracted, and they are condenſed at laſt into drops of water. The igneous fluid ſtill decreaſing, the particles drawing near together, loſe their reſpective mobility, and concrete into ice.

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† It is cuſtomary, among philoſophers, to uſe the words, Liquid and Fluid, indiſcriminately, as ſynonimous terms. However, I would here make a diſtinction; and comprehend, by a liquid, ſuch as is indeed fluid; but, under the ordinary preſſure of the air, acquires a ſuperficies parallel to the horizon; whereas, a fluid does not always anſwer ſuch a definition, as may be ſeen in flame and ſmoke.

‖ Vide, on Elective Attractions.

It reſts with me now to offer a theory, that ſhall not only ſerve to illuſtrate theſe changes, but many other facts relating to heat; ſince the ideas commonly entertained on the ſubject of liquidity, conſidered as an effect of heat, ſeem no way ſatisfactory; nor more are they conſiſtent with ſeveral, curious phenomena here preſented to us *. A notion generally prevails, that

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* There are two opinions concerning the change which temperature bodies undergo, when they alter their ſtate, or mode of combination. Some philoſophers ſuppoſe, the capacities of the bodies are changed, and, therefore, require more or leſs heat, to occaſion ſimilar mutations of temperature, than they did before; others affirm, that the heat which diſappears,

that water, whilſt paſſing from a ſolid to a liquid ſtate, receives no more heat than can be aſcertained by a thermometer, and that its ſeparation alone is enough to reduce the water into ice. Liquidity, however, we are perſuaded, on the authority of the illuſtrious Dr. Black, does not reſult ſo directly from the ſenſible heat contained, as from a portion of heat concealed in the maſs in a quieſcent ſtate, ſo as not to be obvious to the touch, or liable to affect a thermometer; and which the water manifeſts a diſpoſition to retain, until it arrives at the point of congelation, when the latent principle begins to emerge, and breaks out gradually under the ordinary form of ſenſible or moving heat *. As long as the proceſs

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or appears, has no relation to the capacity, but is either received in combination, as a principle of the bodies, or given out as ſuch. Vide, *Notes to Fourcroy's Natural Hiſtory.*

* To be better underſtood, I denominate the heat meaſurable by the thermometer, ſenſible, and in the way of contradiſtinction, ſuch as fixed by the attraction of bodies, ſo as not to be indicated by this inſtrument, ſpecific, or latent. Here then are two kinds of heat; or rather, indeed, the ſame, exiſting under two different ſtates: the former is ſimply diſſeminated, and may be driven out by preſſure alone, or by mechanical means; the latter, being in a ſtate of true combination, does not deſert the body it aſſociates with, but in conſequence of new chemical combinations.

is going forward, the water nevertheleſs perpetually deriving cold from the neighbouring bodies, will not freeze before the whole of the ſpecific heat is ſet at liberty; and at the ſame time the ſenſible heat falls down to the temperature of the ſurrounding medium. Therefore, admitting ſenſible heat as eſſential to liquidity, ſtill the more immediate and indiſpenſible cauſe conſiſts in what heat is abſorbed by the water ſecreted in it, and withal preſerving the ſame condition, without increaſe or diminution, during the whole continuance of the liquid ſtate.

In order to come at better information reſpecting this quality of heat received by the ice, and to form ſome eſtimate of the quantity, Dr. Black had recourſe to experiment. He procured two wide-mouthed, Florentine flaſks, and meaſured out into one of them five ounces of water, which he afterwards congealed, by means of a frigorific mixture placed on the outſide; the bottle was put upon a circular wire, and fixed into the projecting end of a writing-deſk, in a ſpacious room, without fire, whoſe temperature might be from 48 to 49 deg. above froſt. He then ſet up the other flaſk, with an equal quantity of water, cooled down near to the freezing point; and into which, in another room, of the ſame preciſe temperature as the former, he immerſed a very delicate thermometer; on obſerving the celerity with which the heat entered the cold water, he was enabled to judge of the quantity that penetrated the ice; and, by attending to the thermometer very minutely, diſcovered, that, in half an hour, the water gained 7 deg. of heat. Now, were the vulgar notion juſt, the ambient air ſhould, in the ſame ſpace of time, ſupply the ice with a ſufficiency of heat for liquifying the maſs, ſince it derives full as much from that ſource; but, contrary to expectation, the greateſt part of the ice remained unmelted, and it was found to require 21 half hours before the whole diſſolved, though the air imparted heat to it, with exactly the like celerity as it did to the cold water. And the Doctor, on keeping his hand under the water-flaſk, for the firſt half hour, and under the ice-flaſk, during moſt of the liquefaction, had the evidence of his ſenſes, that the room was communicating heat to the latter; for he felt a ſtream of cold air gravitating downwards, and cooling his hand, if even held at the diſtance of more than a foot from the veſſel. Thus we are furniſhed with a very ſenſible and plain criterion, by which we may determine, whether an abſorption, or ſeparation of the matter of fire, has taken place in any combination. In the firſt inſtance, cold will be produced in the ſurrounding bodies; in the ſecond, there will be an augmentation of heat. The Doctor hit upon another experiment: inſtead of expoſing the ice to warm air, it was inſtantly mixed with warm water; knowing that, in conſequence, the temperature would be in an arithmetical mean of the two extremes; and, in fact, nearly turned out ſo, when examined by a thermometer. But, taking ice in place of water, the caſe was otherwiſe, ſince the temperature became remarkably colder. So a quantity of heat ſuddenly diſappears, which, ſuppoſing it all accumulated in the maſs, is computed to augment the ſenſible heat of the water, upwards of 140 degrees. The deficiency of heat, ſome alledge, is not intimately combined with the water, but totally ſuffocated and deſtroyed*; if, however, we detect any eſcaping on the return of a liquid into a ſolid, it will be quite ſufficient to ſhew that the heat is only repreſſed; for tho' coming off very ſlowly, yet this revival of it, as it were, is diſtinctly perceived.

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* A great number of facts have eſtabliſhed it as a certainty, that this body, or modification, is unalterable in itſelf, and is not deſtroyed, or loſt. And theſe have induced Meſſrs. Lavoiſier and De la Place, to give the following important principle, as an axiom, reſpecting the appearance and diſappearance of heat.—"If in any combination, or change of ſtate whatſoever, there be a diminution of free heat, this heat will appear again undiminiſhed, when the ſubſtances return to their firſt ſtate; and reciprocally, if in any combination, or change of ſtate, there be an augmentation of free heat, this new heat will diſappear, during the return of the ſubſtances to their original ſtate."—In rendering this principle more general, and extending

An experiment of Farenheit's, carries with it the fulleſt conviction imaginable, that the liquefaction, in reality, is owing to the ſpecific heat, whilſt the ſenſible heat is only a means, or condition, towards retaining the former. He poured ſome water, previouſly divorced of its air, by coction, into a glaſs ſpherule, which was afterwards hermetically ſealed; and on being ſubjected to the cold of an exceſſive hard, froſty night, the water ſtill continued perfectly liquid; but when in this ſtate, he broke the glaſs, or gave it a ſudden ſtroke, the congelation commenced no ſooner [*].

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extending it to all the phenomena of heat, they have uſed the following mode of expreſſion.——"All variations of heat, whether real or apparent, which are experienced by a ſyſtem of bodies, in changing their ſtate, will be re-produced in an inverſe order, when the ſyſtem paſſes again to its firſt ſtate."

Fourcroy's Elements.

[*] I formerly ſignified, the reaſon aſſigned by Dr. Blagden, for water freezing more rapidly after ebullition; but am now prepared to offer a different view of the matter. When the air of the water is diſſipated in boiling, the liquid recovers as much

Open veſſels will, in every reſpect, anſwer the ſame; and, therefore, the apparatus deſcribed, is not abſolutely neceſſary; ſince, by placing a tea-cup full of water, though ſeveral degrees below froſt, on the outſide of a window, in calm weather, its temperature aſcends to that of the air, without freezing. Some have imputed this circumſtance in the water, to its ſtate of repoſe, and peculiar arrangement of its particles, as, in truth, the commotion is ſucceeded by an inſtantaneous congelation, which, if depending altogether upon the diſturbance and liquidity, merely upon any arrangement of the particles, we ſhould expect the whole of the liquid to congeal, and the heat to continue preciſely the ſame as it was, antecedent to the diſturbance *. But only a ſmall portion of the water

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from the atmoſphere, by virtue of the forcible attraction ſubſiſting between the two elements. Hence, as the air re-enters, it occaſions a certain motion amongſt the particles of the water, which has a tendency to evolve its ſpecific heat; and this ſame cauſe, perſiſting to act, the whole of the latent principle is expended, and congelation inevitably follows.

* Not every manner of motion, however, Dr. Blagden conjectures, but only ſuch as by a kind of tremulation, rather agitates ſmall portions of the water ſeparately, than the whole collectively. Nay more, the electric ſhock expels all the heat, and ſo gives the effect, as will alſo happen from the contact of ice. And the Doctor employs this fact, to explain the freezing of

water is cryſtallized; and, what ſeems ſtrange, it is this ſame ice affords the heat, which diffuſes itſelf through the remaining liquid, ſo as to raiſe the thermometer, in a moment, 10 or 12 degrees, and hinder it from parting with any more latent heat, till again cooled down to ſomewhat below the freezing point.

The intenſe cold produced by the different ſalts, with ſnow or ice, can be explained after the ſame manner. Water, when impregnated with ſalt, is far more retentive of its liquidity, than if pure, or free from ſuch admixture; in ſo far, that a ſtrong brine, bears cooling down to nought. Wherefore, on mixing ſnow and ſalt, whoſe temperatures point at froſt, we have here ſubſtances united together,

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of water expoſed uncovered to the cold air, in which icy, or frozen particles, are almoſt always afloat, and though ſeldom large enough to be viſible, yet make themſelves felt, by infringing upon our ſkin. The ingenious author, further verifies this elegant ſolution, by experiment; and aſcribes the efficacy of oil, in preventing the congelation of water, in which it ſwims, intirely to the ſame principle. Upon the whole, he, endeavours to account for theſe phenomena, by ſuppoſing the particles of water poſſeſſed of a ſort of polarity; that is, to have particular attracting points, or ſurfaces, whoſe attraction is counterbalanced by a certain quantity of latent heat, and which ruſh together, when the heat is ſufficiently diminiſhed.

Phil. Tranſ. vol. 88, *part* i. *art.* xi.

containing a ſurplus of heat more than is requiſite to liquefy the maſs. So, the ſnow, being firſt melted, diſſolves the ſalt; but, to accompliſh this end, they demand either the abſorption of ſenſible, or the aſſiſtance of ſpecific, heat, from ſome ſource or another; however, as we have no extraneous heat thrown in, the ſuperfluous ſtock is employed, which ſuddenly changing from ſenſible to latent, enters into the compoſition of the liquid under that form. According to the nature of this experiment, vaſt cold is generated during the liquefaction *, and yet its degree muſt be limited; for, as ſoon as the reciprocal action between the ſalt and ſnow becomes extinct, the utmoſt cold will enſue, no more heat being abſorbed in a latent ſtate; but the cold of the mixture is never greater than what brings down theſe bodies to the beginning of the ſcale; as they are no longer given to act upon one another, and a little below that, loſe their fuſibility.

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* This change of temperature, ſome would underſtand on Dr. Irwin's principles; conceiving, that by the union of certain bodies, a mixture is formed, whoſe capacity for heat is greater or leſs. In theſe experiments, it is of ſome import, to obtain the ſalt well powdered; for the finer it is, the more ſurface has the water to act upon; and, conſequently, quicker the ſolution performed: when groſsly powdered, the capacity may be apparently changed by the heat, loſt in the time required to penetrate the maſs.

lity. We ſee then, in the inſtance before us, the production of cold is exactly the converſe of the former, wherein agitation had to do with; therefore, the diſturbance, is only the occaſional, or accidental cauſe of the water's freezing, which cannot happen, without the latent principle iſſues forth, and which, as we formerly obſerved, is the more immediate and indiſpenſible cauſe of liquidity.

Next, as to the more general properties of water, in its ordinary ſtate.

If we except fire, water is the moſt penetrative of all bodies, and the moſt difficult to confine; this has been inconteſtibly proved, by a variety of experiments. It is, in fact, more fluid than air; and, as ſome pretend to aſſert, makes its eſcape by pores, ten times ſmaller; however, the tenuity of its parts is ſuch, as to have actually penetrated through gold. This we are taught from the Academy del Cimento, who, by order of the Duke of Tuſcany, included a quantity of water in a ſpherical veſſel of gold, ſubjected to great preſſure, when the liquid, rather than yield, exuded through the pores of the metal, ſo that the ball was all over wet on the outſide. From theſe premiſes, the elaſticity and compreſſibility of water, have been denied by Boerhaave, and others; but an intereſting ſeries of experiments by the Abbé Mongez, go to prove the former, and even ſhew the ſame is confirmed by the academicians. And as to its compreſſibility, Mr. Canton has, by means of the receiver of an air-pump, put the matter beyond all diſpute.

Water viewed merely as an element, may be ſaid to contain air between the interſtices of its parts, which, by mechanical compreſſure, intimately incorporates with the water. And when deprived of its air, either by froſt, heat, or long continued agitation, it has the property of recovering as much from the atmoſphere as it had loſt; and this re-abſorption, becomes the leſs powerful, in proportion to the degree of impregnation. As to the quantity of air capable of being diſſolved and retained in ſolution, that muſt depend partly upon the temperature of the water, partly upon the weight of the atmoſphere, and probable enough, as Dr. Watſon ſuggeſts, upon the water's purity. Boerhaave deduces, that the air ſeparated, equals the water in bulk. The Abbé Nollet, on having purged a quantity of its air, found it abſorbed, in ſix days only, one-thirtieth of its bulk. Dr. Hales obtained, by diſtillation, no better than one cubic inch of air from 54 cubic inches of water. Again, M. Eller makes the quantity not to exceed above 150th part of the whole. A pint of Dr. Prieſtley's pump-water, contained about one-quarter of an ounce meaſure of air, or in point of bulk, in the proportion of 64 to 1. The water of the Seine at Paris, after it was boiled, M. Fontana reports, took up, in 40 days, one-twenty-eighth of its bulk of common air. Mr. Cavallo obſerved water in a temperate degree of heat, and when the barometer was 29 inches and a half, to abſorb about one-fortieth of its bulk. Laſtly, on the authority of Bergman, air is combined in moſt waters, in the proportion of about one cubic inch to a kanne. So we perceive the fallacy of experiments; and how far either of theſe aſſertions holds true, is left to others to determine.

Reſting on the obſervations of M. le Roy, I preſume only to ſurmiſe, there is no air in nature deſtitute of water, nor any water without air.—— The Biſhop of Landaff wiſhes to aſcertain, with preciſion, at what degree of heat water begins to part with its air; he fixes it at 60 deg. ſtill adding, that air may paſs off in a lower temperature; but as the atmoſphere's gravity is equally to be taken into account, I cannot ſay I am perfectly ſatisfied with his concluſions.

The ſpontaneous evaporation of water formerly ſpoken of by us, as a ſource of cold, comes now properly to be regarded as an effect of heat; and by it we underſtand, a vapor void of elaſticity, ariſing in a certain temperature, and occaſioned, ſlowly and imperceptibly, without the leaſt emotion. The comparative evaporation of water and earth, during a ſummer's day, we learn from Dr. Hales, is as 10 to 3; and, in the middle of winter, water evaporated one twenty-one part of its bulk in 9 hours, and ice, one thirty-one part. Electricity is uſually aſſigned as a cauſe of this phenomenon; though the ſubject has not hitherto been clearly developed. The parts of water appear in perpetual, inteſtine motion, yet of what preciſe ſhape would be fruitleſs to enquire, and every trial only marks the futility of the attempt. Some have not heſitated to pronounce them globular; but this is ſurely hypothetical, nor can there be any reaſon for thinking ſo, ſince liquidity is well imitated by a compoſition, whoſe parts are of diverſe forms and ſizes. Hence Sir Iſaac Newton, in his Principia, talks of ſand and powders, as of imperfect fluids; nay, every elaſtic fluid is compounded of a baſe more or leſs ſolid, and the matter of heat. In the ſandy deſarts of Arabia and Africa, the earth is ſo parched and comminuted by the rays of the ſun, as to mount up with the ſmalleſt breeze of wind; and thus being compoſed of atoms almoſt as ſmall as thoſe of water, exhibits a ſimilar appearance, rolling onwards in waves like the troubled ſea, and overwhelming all it meets with inevitable deſtruction.

Even philoſophers of our own time, hold water to be nothing elſe than a congeries of ſolid particles of earth, kept liquid by heat. Says Bergman*, "Since ſand, in a very attenuated and volatile ſtate, preſerves a level, ſo that animals may be drowned in it; ſince pounded gypſum, ſet in a kettle, over the fire, ſeems liquid; not to mention other inſtances, why may not liquids, in general, be conſidered as ſolid molecules too ſubtile, to be perceived by the ſight, however aſſiſted; and on account of their levity, bulk, figure, or by the interpoſition of another fluid, moveable with the greateſt eaſe, and affecting an horizontal ſurface?"

All then we know is, that the parts of water are ſo extremely minute, as to flow over each other with the utmoſt facility; and that fire, earth, and air, conduce to their disjunction.

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* Vide Elect. Attract.

THIRDLY,

Water in a State of Fluidity, or Vapor.

THE aeriform ſtate ſuppoſes, as I have elſewhere expreſſed, the preſence of a large portion of combined fire; therefore, on the principles aſſumed, would fairly infer that water, through all its poſſible ſtates of aggregation, varies only in the quantity of heat appropriated to produce the changes reſpectively in each; and, under ſuch circumſtances, may be now alledged to contain a total ſum of heat, conſiſting of as much as is neceſſary to conſtitute the ſeveral forms of ſolidity, liquidity, and fluidity. But to be further intelligible on the production of vapor, I will imagine a ſingle drop of water poured into a ſphere of copper or braſs, perfectly exhauſted of air, and capacitated to hold ſome gallons; here, on the application of heat, the water ſuddenly diſappears, under the form of a tranſparent vapor, which immediately fills up the whole cavity; by throwing in more heat, its elaſticity and expanſion augment ſo, as even to burſt the globe, or has been known to elevate a weight of twenty tons; and the dilation ſuch, that, by the moſt accurate computation, was found ſound to occupy 1,400 times the ſpace it poſſeſſed before. The Eolipile furniſhes an inſtance of the great rarity and elaſticity of water: as alſo, that excellent and uſeful contrivance in mechanics, the fire-engine: a cubical inch of water worked up into ſteam, takes up 1,600 cubical inches, or upwards.

Reſuming, in part, the theory of latent heat, let us direct our views, for one ſingle moment, to the phenomenon of ebullition. Since water can be heated, in about a quarter of an hour, from 50 to 212 deg. it evidently gains 162 deg.; if, therefore, the vaporific ſtate depended upon the mere increaſe of ſenſible heat, ſurely, in a few minutes more, the whole liquid ought to give itſelf out in vapor; but obſervation inſtructs us, a much longer time is required; for, though the heat perpetually flows in, it no ſooner is concealed in the water and ſteam, ſo that they do not become perceptibly hotter, pointing exactly at 212 deg. as may be aſcertained by ſuſpending a thermometer in the head of a ſtill. And Dr. Black confined a ſmall quantity of water in a phial cloſely corked, with a thermometer incloſed, which having ſet on a furnace to be heated gradually, he remarked, the degree of heat, communicated, was conſiderably beyond the boiling point; and, by unſtopping the phial, contrary to what one would have expected, inſtead of finding the water altogether in a vaporous form, a ſudden tumultuary boiling, with a partial eruption of ſteam, beſides ſome water, enſued, at the ſame inſtant the thermometer ſunk down to 212 deg. Here then is an abrupt tranſition of ſenſible into latent heat; and that the former is only repreſſed but not annihilated, will eaſily be granted, ſince we diſcover, in the diſtillation of water, during the condenſation of ſteam, by means of the refrigeratory, a degree of heat far greater than can be accounted for, from the ſenſible heat of the vapor, as being capable, if thrown into water, of heating it 800 deg. ſo requiring a temperature almoſt approaching to ignition. Moreover, in experiments of a ſimilar nature, proſecuted by Mr. Watt, of Birmingham, on Papin's Digeſter, the accumulation of heat was eſtimated at 1000 deg. notwithſtanding the ſteam paſſed off, all the time, with a very moderate heat. From hence we may fairly deduce, that the operation of fire, in giving liquidity, and vapor, is alike.

If, in explaining theſe alterations ſo ſuſceptible to water, recurrence is had to the powerful agency of heat, there are yet circumſtances to be regarded, as promotive, or otherwiſe liable to retard ſuch. The gravity of the atmoſphere has a ſingular influence over water, even ſo much as to prove an obſtacle to its evaporation; and to this, probably, we might aſcribe the preſervation of the ocean, in a liquid ſtate; for, in proportion as the weight is greater, will the tendency in the water to become rarer, be oppoſed: ſo, on the one hand, the degree of heat diſpoſes to evaporate it, whilſt, on the other, the ſuper-incumbent atmoſphere reſiſts its evaporation, thus, taking a fluid or liquid ſtate, according to the prevalence of either of theſe powers. It follows, of courſe, that water boils more readily in a lower degree of heat, on the ſummit of mountains, than in the vallies, or on plains leſs elevated *. But its converſion into vapor, under the common weight of the atmoſphere, is pretty ſtationary, the greateſt variations hardly exceeding above a degree †; and when once having properly attained the uſual boiling point, is not capable of

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* All fluids willingly give themſelves out in vapor, at great heights; and, for this reaſon, liquids loſe part of their ſtrength on high mountains, as has been noticed by philoſophers, and lately by M. de Lamanon, at the height of more than 1800 toiſes above the level of the ſea,

† Some curious barometrical experiments of Dr. Walker's, the profeſſor of Natural Hiſtory at Edinburgh, ſuggeſt, that for every 407 feet we aſcend any mountain, the heat of boiling water diminiſhes one degree.

conceiving additional heat, it affording a ſtandard, fixed degree, all over the world: being of an equal temperature in Greenland, as upon the coaſt of Guinea.

Mr. Boyle has demonſtrated, that, by the total abſtraction of the circumambient air, from beneath the receiver of an air-pump, water boils impetuouſly at 120 deg. and continues ſo doing until lukewarm, deſcending to about 90 or 95 deg. its ordinary boiling point, in vacuo. But ether, in conſequence of its high volatility, requires little more than animal heat to convert it into vapor, when ſubjected to the preſſure of the ſurrounding air; if, however, put under an exhauſted receiver, it boils in the intenſeſt cold imaginable: that judging, were it not counteracted by the above cauſe, it would, for ever, be in a vaporous ſtate, and its point of ebullition below the temperature of our air. Hence the diſcrimination of elaſtic fluids, into permanent and non-permanent, has actually no foundation in nature, any farther than relates to the heat and preſſure felt in our climate, and in moſt of the habitable parts of the world. And, from all theſe facts, we conclude, that all vapor, air, and, in general, every elaſtic, aëriform fluid, is a combination of the matter of fire with a fluid, or even with any volatile, ſolid body; and that volatility is nothing elſe, but the property which bodies poſſeſs, of being, in ſome manner, diſſolved, of combining with the igneous fluid, and, with it, forming aëriform fluids.

On the Compoſition of Water.

THE learned of the preſent day, zealouſly contend, whether pure water is merely an elementary ſubſtance, or derived from the intimate aſſociation of ſeveral kinds of air; as though affecting the moſt ſtriking characteriſtic of ſimplicity and uniformity of ſtructure, many of the late expedients uſed, favor an aërial compoſition, which indeed, has already, in ſome meaſure, been exhibited by the diverſity of appearance ſhewn by this deluſive body, in a variety of circumſtances. Water is known, in certain caſes, to accelerate combuſtion; and when highly rarefied, will, for a while, have all the properties of true air, if excepting, that by refrigeration, it again returns to its original ſtate *. But, conformable to the recent opinions of chemical philoſophers, water conſiſts of *dephlogiſticated* and *inflammable* airs, or, as Mr. Watt ſuſpects, of the former air, and phlogiſton, deprived of part of their latent heat.

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* Air is defined to be a fluid whoſe particles are not in contact, and repel each other, which repulſion may be diminiſhed but not deſtroyed, by any degree of cold yet experienced in the vicinity of the earth: vapor again implies a fluid, the expulſion of whoſe particles can be deſtroyed by cold, and the whole condenſed into a groſs fluid, by their coalition.

Mr. Cavendiſh, whom we may ſafely conſider as the diſcoverer of the compoſition of water, obſerved, that on deflagrating together theſe two airs, in cloſe veſſels, they were condenſed into water. But when the proportion of inflammable air was ſuch, that the air remaining after the combuſtion, was but ſlightly phlogiſticated, the reſiduum of water contained a ſmall quantity of nitrous acid: on the contrary, when the inflammable air was in larger proportion, the liquor had not this acidity, which, therefore, ſeems very much to depend on the degree of phlogiſtication of the air. Says Mr. Higgins, " When the airs worked upon are pure, and when the inflammable air prevailed, I never obſerved, by the niceſt teſt, the preſence of an acid. When the dephlogiſticated contained one-eighth phlogiſticated air, I obtained nitrous acid in great abundance. Hence I infer, if we could procure dephlogiſticated air entirely free from phlogiſticated, that not a particle of any ſort of acid would be produced *.

On another occaſion, Mr. Cavendiſh conſumed 500,000 grain-meaſures of inflammable, with about two times and-a-half the quantity of common air, and, by cauſing them to paſs through a glaſs tube,

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* Vide Higgins's Comparative View of the Phlogiſtic and Antiphlogiſtic Theories.

eight feet in length, 135 grains of water was obtained. And a conſequence he draws from all his experiments, is, that water is, in an intermediate ſtate, between pure and inflammable air.

Mr. Warltire notifies, in Dr. Prieſtley's Work, that when a mixture of common and inflammable air was fixed, by means of the electric ſhock in a cloſe, glaſs veſſel, though dry before, became immediately dewy. In the purſuit of this experiment, diverſified with the ingenuity and addreſs of Mr. Cavendiſh, the moiſture appeared conſtantly proportional in quantity to the phlogiſtication and diminution of the air; and one quarter of an ounce of the dew being curiouſly collected for examination, proved to be no other than pure water, whoſe ſpecific gravity was to diſtilled water, as 10010,25 to 10000.——Several experimentaliſts have ſince improved upon theſe obſervations; as Prieſtley, Kirwan, Withering, Keir, and Higgins, in England; and Lavoiſier, Le Roy, Berthollet, Bayer, Pelletier, Meuſnier, Mongé, De la Place, Bucquet, Mongez, Le Fevre de Guineau, with many others on the continent †.

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† For a particular account of what has been done on this ſubject, I muſt refer the reader to the tranſlator's preface to Fourcroy's Natural Hiſtory. See alſo Dr. Harrington's Letter.

In vindication of the decompoſition and recompoſition of water, Lavoiſier conciſely relates an experiment very cautiouſly conducted by himſelf, in conjunction with M. Meuſnier: that of introducing the vapor of water into a red-hot gun-barrel, during which the metallic matter underwent calcination, accompanied by the copious diſengagement of inflammable gas. The metal was increaſed in weight, and the addition, together with the weight of inflammable air, correſponded perfectly with that of the quantity of water deſtroyed. The portion of iron calcined in this experiment, was found ſeparate from that which had not ſuſtained the ſame alteration; it formed an interior cylinder, thicker, and of a texture, colour, conſiſtence and form, very different from that of the external part. The heat of red-hot iron is neceſſary, in order to ſucceed, becauſe it ſingularly promotes the ſeparation of the principles of the water by the metal; for which reaſon, when the gun-barrel is not well ignited, and the water does not paſs in a ſtrongly elaſtic ſtate, inflammable gas is not diſengaged, the water not being decompoſed; and, a want of attention, perhaps, to this circumſtance, has cauſed ſeveral philoſophers, who did not ſufficiently heat the iron, and introduced liquid water, to deny the decompoſition of that fluid. M. Lavoiſier, together with his aſſociate, proceeded to extinguiſh red-hot metals in water, under an idea of reſerving the inflammable air, but whoſe production manifeſted itſelf only from iron and zinc. A copper tube was, therefore, employed, inſtead of the former; and pieces of iron, carefully weighed, put into it; when proſecuted with theſe variations, and allowance made for what water had eſcaped, the weight of inflammable gas, added to the increaſe of the weight of the iron, turned out preciſely equal to that of the original water concerned in the operation, which, ſay they, contains ſix parts of dephlogiſticated air, and one of inflammable air. And M. Lavoiſier, in poſitive terms, aſks, how is it poſſible even to doubt of the fact, when ſeeing that, on exploding 15 grains of inflammable, and 85 of dephlogiſticated air, they afford exactly 100 grains of water, which again, by decompoſition, imparts the ſame principles in the ſame proportion? The reports of Le Fevre de Guineau *, communicated to the Royal Academy in the courſe of laſt year, ſince they accord, for the moſt part, with what we have above recited, will not here neceſſarily require of us any detail.

After all, many inferences are drawn from the chief of theſe experiments, which lead to much

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* See Analytical Review for January, 1789.

doubt and a general heſitation, and the concluſions were publickly oppoſed, almoſt immediately, by M. de la Metherie. M. Volta equally conſiders water as not admitting of decompoſition; and that it forms inflammable air, in conſequence of its union with phlogiſton, and dephlogiſticated air with the matter of heat. M. Fontana, an Italian chemiſt, engaged early in this warfare. His memoir publiſhed at Florence was followed by a letter to Dr. Ingenhouz, and another to the Chevalier Lorgna. He acknowledges, water is loſt in the experiment of the gun-barrel, but will have it, the iron tube gains proportionably in weight. All the air he could procure from water, in the ſpace of three hours, did not amount to one-fourth of the contents of his veſſel; however, it might be alleged, the heat employed was not powerful enough for the decompoſition of water, as well as that the calcination of iron, by ſteam only, ſhews, it muſt have acquired dephlogiſticated air, which can only be produced from the water, while its other ingredient appears unchanged. Fontana, diſapproving of dephlogiſticated air as a conſtituent in the calces of metals, is eager to look out ſome mutation in the ſtate of the water, independent of decompoſition, to explain the calcination of the iron.

The ſmall quantity of fixed air, which remains after the combuſtion of the two airs, is a ſource of great difficulty. The water is ſaid, by ſome, to be depoſited by the gaſſes, and to leave this reſiduum; but M. Adet, a celebrated chemiſt, attributes its riſe to tke impurity of the airs.

Neither have Meſſrs. Giorgi and Ciogni been able to extract inflammable air from water. The former, thinks it is unjuſtifiable, to rely on the experiments of Cavendiſh, Lavoiſier, Meuſnier, &c. in conceiving water to conſiſt entirely of dephlogiſticated and inflammable airs; and, with others, he refers the inflammable gas to the metallic tubes, obſerving, what is worthy of attention, that, if the water be heated a little above the boiling temperature, not a particle of inflammable air will eſcape, but the whole water is gradually converted into atmoſpheric air, impregnated with a particular odor; or, as Mr. Kirwan ſuſpects, into fixable air. Mr. Giorgi obtained air of nearly an equal weight to the water concerned in the operation, when the ſteam paſſed through tubes of copper, porcelain and glaſs; but which being ſomewhat aromatic, led him to ſurmiſe, that the odorous principle formed a component part of the water, and it was rather more pure than common air; hence he concludes, water is compoſed firſt, of dephlogiſticated, and ſome other air, whoſe nature is as yet unknown. Secondly, that heat, or phlogiſton, may give a ſtate of permanent elaſticity to liquids. And, laſtly, that the elaſtic fluids are conducive to the change of water into a permanent, aëriform ſtate.

The truly indefatigable Dr. Prieſtley, whoſe name will always be revered, aims a dangerous blow againſt the doctrine of the compoſition of water, which, though, at firſt, he did not heſitate to embrace, ſtill retained a determination to inveſtigate the ſubject more minutely; and, in ſome experiments lately read before the Royal Society *, is inclined to reaſon differently from what Mr. Cavendiſh, and his adherents, have done.

The coincidence of weight, ſo rigorouſly inſiſted on by Lavoiſier, and which evidently makes the baſis of the new theory, Dr. Prieſtley aſſerts, is poſitively without foundation. He entertaining ſuſpicions, that moſt of the water gained from the combuſtion of the two airs, by the electric ſpark, was no proper conſtituent, but diffuſed through

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* See Phil. Tranſactions, 1788, part ii.

them; ſo every precaution had been adopted to diveſt them of it, previous to detonation. In theſe trials, the weight came far ſhort of that of the air decompoſed; and, inſtead of air being a component part of water, he reverſes the propoſition, by pronouncing the latter to be derived from the former. His important remarks reſt chiefly on a probability that the water contained in the airs, into whoſe conſtitution he ſuppoſes nineteen-twentieths to enter, whilſt one-twentieth part is the acidifying principle, is ſufficient to account for the quantity depoſited during the deflagration. Water, as a conſtituent of inflammable gas, is now tolerably well authenticated; but Prieſtley conſiders it equally an ingredient in dephlogiſticated, in phlogiſticated, and in fixed air.

The aërated terra ponderoſa, betrays no water in its compoſition; nor more does it afford any fixed air, till the water is introduced, and 43 or 44 grains of the liquid are conſtantly expended in the product of 100 grains of air. Poſſible enough too, ſays our ingenious experimentaliſt, ſomewhat ſimilar prevails in every other kind of air, ſince water is concerned in the formation of them all, and is their proper baſis, or the ſubſtance without which no aëriform fluid can ſubſiſt; and, therefore, adds he, the decompoſition and recompoſition of water has never rightly ſucceeded, in any experiments yet deviſed *.

Such is briefly the ſtate of this celebrated queſtion, in which we perceive more difficulties than certainty. The balance of argument, as it here ſtands, perhaps, inclines towards Lavoiſier; though, confeſſedly, the modern hypotheſis builds on in-

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* Two opinions are maintained on the ſubject of the compoſition of water. The antiphlogiſtians ſtate, that the calcination of iron by ſteam, and its reduction by heating in inflammable air, conſiſts ſimply of the decompoſition of water, whoſe dephlogiſticated air aſſociates with the metal, whilſt the inflammable air of the decompoſed water effects its eſcape; and, on the other hand, that the reduction of the metal, ariſes from the expulſion of the dephlogiſticated air, which combines with the inflammable air, and again forms water. Now, ſay they, if a body be preſented to water, which has a ſtronger affinity to one of its conſtituents, meaning either of the two airs, than that which tends to keep them together, a decompoſition takes place, and the principle, not attracted, will be ſet at liberty; and thus iron, tin, oil and charcoal, are known to poſſeſs the property of ſeparating the component parts of water from each other, by abſorbing the dephlogiſticated air, and diſengaging the inflammable gas. The advocates for phlogiſton contend, that the water itſelf uniting with the iron, expels the phlogiſton, which, in the reduction, again re-enters, whilſt the water is extricated.

See Higgins's elegant Treatiſe on the Phlogiſtic and Antiphlogiſtic Theories.

ferences, and theſe rather ſerving to invalidate the old than confirm the new theory; ſo, after all, as to the eſtabliſhment of the poſition, future experience can beſt decide upon. I have only to ſubjoin, that the Royal Academy of Sciences at Orleans, announce a prize of 800 livres to be awarded before the end of the preſent year, for the moſt rational ſolution of the ſubſequent queries: viz.

Is water a compound, or a ſimple element? Is the water, obtained by the exploſion of inflammable and dephlogiſticated air, generated in the act of combuſtion, or is it ſimply diſengaged; that is, does it only proceed from the combuſtion of the pure air, or of its baſis alone with the inflammable air; or, whether this pure air, and all other elaſtic fluids, are not themſelves a modification of water, produced by its combination with the matter of fire, or light, or of heat?

Sapientis medici eſt, eorum locorum aquas ubi medicinam facit, convenienti examine probè ſcrutari, quo poſtea cum fructu, tam præſervandi quam ſanandi gratia, iis uti poſſet.

HOFFMAN.

ON THE MEDICINAL QUALITIES OF COMMON WATER, &c.

EVER ſince the days of Hippocrates, down to the preſent period, phyſicians have univerſally acknowledged, the ſelection of water to be of the utmoſt importance to human health: a ſubject, indeed, with which all ages cultivated an acquaintance, and has occupied the thoughts of ſo many reſpectable writers, as would ſcarce ſeem now to require any further inveſtigation. An obvious diverſity in the ſenſible qualities of water, joined to medical obſervations, might alone ſuggeſt the idea of its exerting conſiderable influence on the conſtitution; and, therefore, no diſtance of time could elapſe, before mankind perceived ſome ſlight diſtinctions, if aſſiſted by no better criterion than that of taſte.

Independent of the impulſe given to animals, in the ſenſation of thirſt, the mere preparation of our food, and more eſpecially the various arts and manufactures which at length took to be ſtudied, muſt gradually have diſcloſed an evident diſagreement in the properties and goodneſs of waters with reſpect to certain purpoſes, although we remain ignorant of the manner and order in which diſcoveries occurred.

The ſanative effects of water are forcibly alluded to in paſſages of Holy Writ, and particularly ſo in a figurative ſenſe, to repreſent the ſpiritual powers of the Meſſiah; namely, in that beautiful pictureſque deſcription, wherein he is metaphorically ſaid to receive refreſhment and confirmation of ſtrength, in the following plain, but extraordinary words:

"He ſhall drink of the brook in the way, therefore ſhall he lift up his head *."

The Greek phyſicians were cautious, beyond meaſure, in the choice of water; and condemned ſuch as was crude, as cauſing flatulence and oppreſſion at the ſtomach. Hippocrates, the father of the healing art, dwells perpetually on the different degrees of purity in different waters; and, on the ſalutary and pernicious effects of each, ſo far as to lay down precepts for depurating thoſe

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* Pſalms, chap. cx. v. vii.

that are concocted, by previouſly boiling them. But, with the ancients, this ſame preparation formed an ingredient in their wines, to render them more grateful and wholeſome; and, in their convivial entertainments, the mixture was regulated by ſtated rules. To this they often added ice; and the practice was greatly improved, by immerſing the veſſel, with the contained wine, and boiled water, into ſnow; by which means it had very ſpeedily imparted to it, a more equal and intenſe coldneſs, as we read of in Juvenal, and as happily expreſſed by Martial *, under the appellation of *nobile frigus* †.

Galen, from knowing this method of preparing the water in his own country, ſpeaks of it in language of admiration; but Celſus gives to Aſclepiades the merit of reviving it among the Greeks. Alexander, in his Indian enterprize at the ſiege of Balta, directed 30 pits to be made, as reſervoirs for ſnow, and, after covering them with ſtraw, in order to ſeclude the external air, ſo cooled his wine and water. Herodotus recites, that when-

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* Non potare nivem ſed aquam potare regentem
De nive commenta eſt ingenioſa ſitis.

† Quo tibi decoctæ nobile frigus aquæ.
Lib. xiv. Ep. 116, 117.

ever

ever the King of Perſia marched his army on an expedition, he drank no other water than what the river Choaſpes ſupplied, which being firſt boiled, and then received into a ſilver vaſe, was ſet apart for his ſole uſe. Athenæus likewiſe corroborates the ſame report, with beſtowing high encomiums upon its waters. Neverthelefs, the aqua martia is ſpoken of as preferable to any for its ſalubrity, in ſo far, as to have led Pliny to value it as a peculiar bleſſing granted by the Gods; and ſo, by reaſon of its ſplendor, was entirely appropriated to drinking; nor would they ſuffer it to be encroached upon, by any indiſcriminate intercourſe *,

The Orientals of old, entertained ſuch juſt, yet too often enthuſiaſtic notions, of the ſuperior excellence of many ſprings, as to hold them in a degree of eſteem bordering on veneration; but even in later ages, ſeveral had their tutelar ſaint, and a few with us, ſtill retain the names of theſe ſaints to whom they were peculiarly conſecrated: as, for example, the Holy Wells at Malvern, and the famous well of St. Winifred †, in North Wales;

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* Sir Edward Barry, on the Wines of the Ancients.

† Tradition hands down to us the following information, concerning the origin of this ſpring.

St. Winifred is reported to have vowed chaſtity; but being ſtrongly importuned, and once purſued by a nobleman of the neighſo renowned ſor their purity, all over England. Thus the latter, ſuitable to the legendary tales of the vulgar, has wrought wonderful cures; and theſe, ſome ridiculouſly aſcribed to the interceſſion of the Saint, whilſt others would, with more probability, impute, inſomuch as it is efficacious, to the water's levity, or freedom, from terreous impregnations. Not enough then to treat of elementary water, ſolely in the way of drink, it equally claims our attention as a medicine. In the cure of febrile complaints, much can be argued in behalf of dilution; accordingly, the practice of throwing in large quantities of watry liquid, is rigorouſly inſiſted on, all over the continent of Europe; and more eſpecially by the Spaniſh and Italian

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neighbourhood, whoſe ſuit ſhe declined, and whoſe embraces ſhe flying from, ſought for protection in the church, where St. Buenno was celebrating maſs, but before the fair virgin could arrive at the ſanctuary, ſhe was overtaken on the hill, near the church, by her incenſed lover, by name Carradoc, who, furious at her reſiſtance, ſtruck off her head, which rolled down the mountain, and, at the place where it ſtopped, immediately iſſued forth the ſpring on which the preſent well is founded, from thence called St. Winifred's Well.——Some fix this miraculous event in 644, others in 660; but, to heighten it ſtill more, it is added, that St. Buenno replaced the head upon St. Winifred's ſhoulders, who was thereon reſtored to life, and lived 15 years after the accident. But ſurely an occurrence fraught throughout with ſuch palpable ſuperſtition, will not deſerve a ſerious confutation.

Italian practitioners, on the uſe of what they term the Dieta Aquæa; which conſiſts in abſtaining from every other ſort of aliment rather than water, of which they give, in divided portions, to the amount of ſix or eight pounds, within the ſpace of twenty-four hours; and, on the authority of Dr. Cirelli, the Neapolitan phyſicians frequently reſtrict the ſick to ſuch a regimen for weeks together *. But, without enumerating the variety of occaſions wherein the

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* It has been proved, in many inſtances, that water alone is capable of ſuſtaining human life a long time. The Philoſophical Tranſactions furniſh us with a memorable caſe of the kind. Some people engaged at work in a deep coal-pit near Liege, had the misfortune to pierce into a ſubterranean current of water, of ſuch impetuoſity, as to have inſtantly filled a great part of the works. The perſon who ſtruck the blow into it, was drowned; and others, that were near the aperture of the pit, very narrowly eſcaped, by being drawn up. In the courſe of 24 days after, when the mine was cleared out, four of the men who had been given over as loſt, were found alive: in fact, they preſerved themſelves, by climbing into a place above the reach of the water, where, providentially, a little ſpring dribbled forth, and which ſerved for their ſupport. Curioſity pointed to an examination of the water, but it had no peculiar matter, any further than the ſparry ſubſtance met with in common, and that not in any quantity. *Phil. Tranſ.* No. 159.

We have alſo an account, in the Philoſophical Tranſactions, of a man, who lived, for 18 years, on no other aliment than water; and, now and then, though ſeldom, clarified whey; and yet he enjoyed tolerable health. See No. 466, ſect. 7.

the expedience of water is judged of medicinally, ſuffice it here barely to mention its two-fold operation on the living ſyſtem; firſt, by virtue of its ſtimulus conſequent upon temperature, it increaſes the action of the ſecretory and excretory veſſels; ſecondly, by its diluent properties, it corrects and ſoftens the circulating fluids, from whatever cauſe depraved; wherefore, we are told by Dr. Cullen *, that its abundant uſe, ſaving a few exceptions, may be employed as a very general means of preſerving health, and redreſſing diſeaſes.

* Materia Medica. Art. Aqua.

A
COMPARATIVE VIEW
OF THE
DIFFERENT WATERS.

NATURALISTS have divided common water into *Atmoſpherical* and *Terreſtrial*, as deſcriptive of the region of Nature from whence more immediately derived. The former diviſion, comprehends the waters of ſnow, hail, ice and rain; whilſt the latter, includes thoſe of ſprings, and lakes, or, indeed, all ſuch as can be met with below, or upon, the ſurface of the earth: not that theſe ſeveral diſcriminations, do more than refer to the different impurities in each, ſince they all agree as water, abſtractedly conſidered.

I. Atmoſpherical Waters.

THE conſideration of ſnow will here, in the firſt place, intereſt our attention.

With reſpect to a philoſophical account of this well-known meteor, naturaliſts are agreed, that it does not conſiſt in frozen water, but frozen vapor.

If, previous to congelation, it was water, it would have concreted into ice; however, as being only vapor, it converts into ſnow. The ſnow we receive, may properly be aſcribed to the low temperature of the air through which it paſſes: when the atmoſphere is warm enough to diſſolve the ſnow before it arrives to us, we call it rain; if it preſerves itſelf undiſſolved, it forms ſnow, which differs from hail and hoar-froſt, in being, as it were, cryſtallized.

According to Signior Beccaria, clouds of ſnow vary in nothing from clouds of rain, except in the circumſtance of cold which freezes them. Both the regular diffuſion of ſnow, and the regularity of its parts, prove the clouds of ſnow to be acted upon by ſome uniform cauſe, like electricity. The ſame ingenious philoſopher even endeavours to ſhew, very particularly, in what manner certain configurations of ſnow are affected by the action of electricity. He was confirmed in his reaſonings on this ſubject, by obſerving, that his apparatus never failed to be electrified, both by ſnow and rain; and, he adds, that a more intenſe electricity unites the particles of hail more cloſely, than the more moderate electricity does thoſe of ſnow[*].

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[*] Prieſtley's Hiſtory of Electricity, vol. i. p. 432.

The lightneſs of ſnow, although it is firm ice, is owing to the exceſs of its ſurface, in compariſon to the matter contained in it. And as to its whiteneſs, that plainly ariſes from the great diviſibility of its particles, ſince ice, when pounded, will become equally white.

Snow-water ranks ſuperior to any, that of hail excepted, in point of purity, whatever contentions may have ariſen among the learned, in other reſpects, regarding it. Boerhaave and Boyle are laviſh in praiſe of, ſuppoſing it to be the lighteſt and beſt of all, becauſe, when properly collected, it is moſt free from foreign admixture. Haller too affirms, he drank it frequently in large quantities with impunity; and, that the flocks partook of it conſtantly, without detriment to their health*. And Dr. Lewis ſays, he has ſeen ſnow-water, which, after many years keeping, was perfectly clear and taſteleſs.

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* Purior eſt equidem cœleſtis Aqua quæ fit ex nive ſuper nivem dilapſa, aut ex contabeſcente grandine, eandemque negant etiam intra multos annos putreſcere; et tandem fatentur non eſſe ſalubrem, in eo quidem multum erraturi. Nihil enim gratiús quam ſapor Aquæ ex ſoluta nive in Alpibus, per nudas rupes puramque terram defluentis, quam ſæpe cum ſumma voluptate, nullo cum incommodo, maxima doſi, per Alpium culmina anhelans bibi, et tota armenta bibunt.

Haller, Phyſiolog. vol. vi. p. 327.

On the other hand, Hippocrates decries all waters diſſolved from ſnow, or ice [*]; and Seneca enquires, whether the latter does not, in courſe of time, give a ſchirrous liver. But, ſo far from this, the late M. Pouteau, doctor of medicine, and chief ſurgeon to the Hotel Dieu at Lyons, recommended the drinking of frozen water, as a remedy for ſchirrous and cancerous tumours, without allowing any other aliment, or medicine, for weeks; and mentions a caſe of Madame Gerard, obtaining a cure of a diſeaſed womb by this means, after all other reſources had failed. And Bartholine, in an expreſs treatiſe, De Nivis Uſu Medico, obſerves, that in Norway, ſnow-water is not only their ſole drink during the winter; but ſnow even ſerves for food; people having been known to live ſeveral days without any other ſuſtenance.

Hoffman, with ſome of the moderns, aſcribe to ſnow-water another not leſs dubious effect. It relates to that noted complaint the Bronchocele, called, by the French, *les goitres*, ſo prevalent in the Alps, Pyrenees, Black Foreſt, and Tirol. "As you advance towards Mount Cenis, you find very few exempt from theſe tumours; which are ſo enormous, and of ſo loathſome an appearance, eſpecially in ugly, ragged, half-ſtarved, old women, that the very ſight of them turns the ſtomach. I was curious in my examination, whether any children are born with this malady: I was informed, that there is no ſuch inſtance; and, even that the ſwelling never begins to form, till towards two years of age; ſome examples of which I myſelf ſaw [*]." And if we can credit Hoffman, ſtrangers become affected in the ſame way, after reſiding there a few years.

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[*] At vero aquæ ex nive atque glacie productæ omnes malæ ſunt. *Hippocrates de Aëre, Aquis et Locis.*

" Water melted from ſnow, or ice, is known always to have this effect; and the conſtant uſe of it in mountainous countries, produces thoſe enormous wens which are common among Alpine nations [†]." However, phyſicians of the preſent day, upon good grounds, reject the notion of the uſe of melted ſnow being a cauſe of ſuch unſightly protuberances, as, in Sumatra, they prevail exceſſively, although the country is entirely deſtitute of ſnow throughout the year [‡]. Again, in Greenland, no other beverage is had recourſe to, and yet theſe enlargements never ſhew; nor more are they ever ſeen in Weſtmoreland, where there is more ſnow, and higher mountains, than either in Monmouthſhire or Derbyſhire, in which places they abound.

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[*] Sharp's Letters from Italy. [†] Forſter's Voyage, vol. i.

[‡] Phil. Tranſ. for 1778.

Dr. Percival * attributes the diſeaſe in queſtion to that quality in water called hardneſs, whoſe nature will fall hereafter to be explained. " One obſervation I cannot omit, that the inhabitants of Mancheſter are peculiarly ſubject to glandular obſtructions, and ſcrophulous ſwellings; and, that water loaded with aſtringent, earthy ſalts, hath a direct tendency to produce ſuch complaints, has been already, I hope, fully evinced."

But M. Villars, of Grenoble, in treating on the local cauſes of the Bronchocele, with perhaps ſtricter propriety, aſſigns its riſe to the cold and humidity of vallies, having but a ſingle communication with open countries †.

Some modern philoſophers embrace the opinion of Ariſtotle, by attributing the real or ſuſpected in-

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* Experiments on the Hard Pump-waters of Mancheſter.

† The Abbé Chappe mentions an epidemic diſeaſe in Ruſſia, of this ſpecies, which the natives cure by the application of tobacco, and ſal ammoniac, well maſticated. A medical gentleman, of veracity, aſſured me, that he frequently experienced the happieſt ſucceſs in ſimilar caſes, from a courſe of hemlock and burnt ſpunge.

ſalubrity of frozen water to the loſs of its air. "Such water, when newly melted, is totally void both of air, and the aërial acid; ſubſtances which we find in greater or leſs quantity, in almoſt all other waters: and hence it is, perhaps, that ſnow-water is noxious to animals *." If, however, the diſeaſe under conſideration, reſulted merely from this cauſe, ſimple expoſure to the air for a time, would ſoon reſtore to the water what principles might have eſcaped during congelation; ſince, when divorced of its air, it readily imbibes afreſh, and becomes ſaturated with, ſhortly. Beſides, we can recollect, that water is equally deprived of its air by culinary heat, as well as by freezing; yet, none of the above effects were ever known to happen from boiled water, though taken at meals, in various forms, by moſt people, every day.

Dr. Rutty carefully analyzed ſnow-water, after the great froſt in February, 1739; and obtained, out of a gallon, four grains of a browniſh ſediment, conſiſting of marine ſalt, abſorbent earth, and a ſmall pittance of oil.

Margraaf, with great precaution, gathered in the ſuburbs of Berlin, in the year 1751, as much ſnow as, when melted, afforded him 100 meaſures of

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* Bergman's Eſſay, vol. i.

water, each containing 36 ounces; and, from the whole he procured, on diſtillation, 60 grains of calcareous earth, together with ſome grains of the marine acid, impregnated with a nitrous vapor. Snow-water, according to Bergman, holds, in ſolution, a ſmall quantity of ſalited lime, and ſlight veſtiges of nitrous acid. The late Dr. Lewis ſuggeſts, that a gallon of it ſlowly evaporated, leaves only two or three grains of ſolid contents; and adds, that diſtilled water itſelf furniſhes nearly as much upon repeated diſtillations; but with this difference, that the reſiduum of ſnow-water, like that of all other natural ones, is browniſh and ſaline; whereas, that of the diſtilled, is a firm, white earth, devoid of ſaline matter, partly calcareous, and partly indiſſoluble.

Snow-water, kept in a warm ſituation, in clean glaſs veſſels, not tightly ſtopped, but covered from duſt, gets putrid in time, though, if more cloſely confined, will remain unaltered for years; whilſt ſuch as is diſtilled, ſuffers no change in either circumſtance.

Hail conſiſts of frozen vapor congealed at a great heighth, and in the moſt attenuated parts of the atmoſphere, as appears by experiment. I incloſed a thimbleful of water in the upper part of a barometrical tube, where there was a vacuum, and only the air of the water admitted; whilſt the ſame was expoſed to an intenſe froſt, the water did not coaleſce after the manner of ice, but took the ſtate of hail, it being white, ſoft, and opaque.

Hail-water, ſince always formed in the moſt elevated regions of the atmoſphere, is better than that of ſnow; and has been found ſo pure, as not to contain above one grain of terreous matter to the gallon.

Rain-water: This, ſimilar to all other waters, takes its riſe from the ocean; but, by an eſtabliſhed law of nature, undergoes a ſort of diſtillation, and is thus purified.

It is the common, received opinion, that rain proceeds from the rarefaction of water carried up to the higher regions by heat, when, from the cold prevailing above, it becomes condenſed, and is precipitated in drops of rain; but it is certain, that clouds are very often taken to the greateſt heighth, without rain, or condenſation, and this would neceſſarily lead one into different concluſions.

Others, conſider rain as an electrical phenomenon; or, at leaſt, ſuſpect that the powers of electricity may concur with other cauſes in producing it. Accordingly, Beccaria of Turin, whoſe obſervations on the general ſtate of the atmoſphere, have been, perhaps, more extenſive and accurate than thoſe of any other perſon, reckons rain, hail, and ſnow, among the effects of a moderate electricity in the atmoſphere; ſuppoſing, that, previous to rain, a quantity of electric matter eſcapes out of the earth, in ſome ſituation or another, where there was a redundancy of it; and, in its aſcent to the upper regions of the air, accumulates, and conducts into its path an immenſe quantity of vapors. The ſame cauſe that collects, will condenſe them more and more, till, in the places of the neareſt intervals, they come almoſt into contact, ſo as to form ſmall drops; which uniting with others as they fall, are depoſited in rain*. Aſſuming, in part, this theory, it is therefore probable, that rain is produced from the clouds being deprived of their electricity, which appears to influence both the evaporation and aſcenſion. And we may remark, that, in a flaſh of lightning, the cloud collapſes, and the rain pours down with redoubled violence: or even in the inſtance of waterſpouts, we could explain their deſcent, upon the ſame principle.

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* Prieſtley's Hiſtory of Electricity, vol. i.

Rain-water is not only contaminated much after the manner of ſnow-water, but charged with adventitious ſubſtances, as is viſible, after ſtanding a-while, from the mucilaginous, or ropy matter, growing upon its ſurface; and which, upon viewing through a microſcope, is compared to a grove of muſhrooms. Moreover, its tendancy to putrefaction, ſhews it to be replete with the ovula of different animalcules; ſome of which, may have been carried down with the rain in its paſſage through the air, whilſt numbers are, perhaps, depoſited in the water during ſtagnation *.

As to its qualities, they vary exceedingly in different ſituations, and ſeaſons of the year; and, to obtain this water in its greateſt purity, it ſhould be collected on the tops of mountains, or on open lands, at a diſtance from houſes: when it has been moderately agitated by winds, and after previous ſhowers. In towns, it is unavoidably impregnated with the ſmoke of chimnies, the waſhings of the roofs of buildings, the vapor of ſlates or tiles, the

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* It is likely, ſays Dr. Falconer, that animals are more diſpoſed to depoſite their ova in rain-water, when ſtagnant, or collected in open veſſels, than in any other kind of water, as it is void of any mineral impregnations, which are, in general, deſtructive to inſects; and, from the like circumſtance, it is more apt to become putrid, than waters ſo impregnated, as theſe ſubſtances poſſeſs, in general, a ſtrong, antiſeptic quality.

the rot, and ſtaminal duſt of vegetables, the ova and excrements of animals; and, by the concurrence of all theſe, often ſending out a diſagreeable taſte and odor. The ſpring, from being moſt temperate, is judged a good ſeaſon of the year for procuring the beſt rain-water; ſince the atmoſphere is then, as it were, clarified by the winter rains, and fewer inſects are generated, or float in it, in compariſon with what they do in the ſummer months; as the experiments of Leuwenhoeck, Redi, and others, ſufficiently prove. In ſome parts of Africa, the drops of rain, in deſcending from the heavens, are uncommonly large, and their acrimony is ſo great, as to erode the ſkin, and ſo putrid, that they quickly cover the cloaths they alight upon with worms [*]. Therefore, Hippocrates judiciouſly enough recommends the boiling or ſtraining of this water, before it can ſafely be uſed; otherwiſe, it has an ill ſmell, and occaſions a hoarſeneſs, and a deep voice, in thoſe who drink of it [†]. Celſus claſſes it among the beſt of waters. "Aqua leviſſima pluvialis eſt; deinde fontana, tum ex flumine, tum ex puteo; poſt hæc ex nive, aut glacie; gravior his ex lacu; graviſſima ex palude [‡]."

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[*] Act. Lypſ. Supplement, tom. i. p. 425. [†] Hippocrates de Aëre, Aquis, et Locis. [‡] Celſus, lib. ii. cap. 7.

Dr. Rutty evaporated ſix ſpecimens of the beſt rain-water he could get at, when a gallon of the pureſt afforded him ſix grains, and a gallon of the moſt impure, 12 grains, of a ſubſtance of a dark-brown colour, with ſome particles of white interſperſed, of a bitter, brackiſh, and ſomewhat lixivial taſte, and offenſive ſmell. The experiments of Margraaf to the ſame purpoſe, pretty exactly coincide with the above: for, out of 100 meaſures of rain-water, each 36 ounces, are procured, on diſtillation, 100 grains of pure, white, calcareous earth, with ſlight additions of the acids of nitre and ſea-ſalt. Therefore, the comparative diſtinctions between rain and ſnow-water, on chemical examination, are very trivial; the firſt containing an acid that is more of the nitrous kind, and whoſe ſolid particles conſiſt of calcareous earth; the ſalt of the latter has more of the marine acid, and leſs earth, yet, both, when expoſed to putrefaction in the warmth of the ſun, manifeſt alike their heterogeneous principles, and produce the ſame effect on metallic ſolutions. But, after all, as the Biſhop of Landaff expreſſes himſelf,—" No two authors perfectly agree in aſcertaining the quantity of ſolid impurity contained in a definite portion of either rain or ſnow-water; this is not to be wholly attributed to the difference of their care and ſkill exerted in the analyſis of them, but principally to the different natures of the ſubjects themſelves, upon which their labours have been employed. The vapors which are daily raiſed from the ſea, may, with great probability, be ſuppoſed to carry with them ſome minute portions of the acid of ſea-ſalt, and, perhaps, of ſea-ſalt in ſubſtance, and of the calcareous earth with which the ſea abounds. The atmoſphere itſelf may be looked upon, not only as the general receptacle of theſe aqueous vapors, but likewiſe of all mineral exhalations; of the ſteams, which are conſtantly ariſing from the perſpiration of whatever enjoys animal, or vegetable life; and from the inſtantaneous putreſcence of theſe ſubſtances, when deprived of life; of the ſmaller ſeeds of terreſtrial and aquatic plants; of the eggs of an infinity of ſpecies of imperceptible animalcules; of the acids and oils ſeparated by combuſtion from all ſorts of fuel; of the matter of light; of electric effluviums; and of a variety of other ſubſtances, which are elevated, and, for a time, kept ſuſpended by natural and accidental cauſes."

Still, upon the whole, we are ſatisfied, that rain-water, when properly choſen, approaches as near to a perfect unmixed element, as we can reaſonably deſire; and will ſcarcely be exceeded by any, excepting that from ſnow and hail, which, as they commonly fall in the colder ſeaſons, are leſs liable to theſe impurities occaſioned by heat.

We proceed to ſpeak of dew.

Philoſophers would fain diſpute, whether dew is formed from the vapors aſcending out of the earth during the night-time, or from the deſcent of ſuch as have been already raiſed through the day.

Gerſton maintains the former hypotheſis; and, in proof of which, he made ſome experiments. In the evening, whilſt there was a copious dew, he expoſed, near the earth, plates of glaſs, ranged at ſeveral diſtances, from one inch to a foot; and obſerved the inferior ſurfaces moiſtened, although the upper were perfectly dry. He next laid pieces of paper on a board near the ground, with one half of the paper hanging over, when he found the projecting part was *only* wetted.

But theſe are no other than equivocal experiments, and ſeem far from proving that dew aſcends, and does not deſcend, as in many nights there is no fall of dew.

However, the moſt remarkable experiments adduced in favor of the firſt hypotheſis, are thoſe of M. Dufay, of the Royal Academy of Sciences at Paris. He ſuppoſed, that if the dew aſcended, it muſt wet a body placed low down ſooner than one placed in a higher ſituation; and, if a number of bodies were thus diſpoſed of, the lowermoſt would be wetted firſt, and the reſt, in like manner, gradually up to the top. To determine this, he placed two ladders againſt one another, meeting at their tops, ſpreading wide aſunder at the bottom, and ſo tall as to reach 32 feet in heighth. To the ſeveral ſteps of theſe, he faſtened large ſquares of glaſs, like the panes of windows, diſpoſing of them in ſuch a manner, that they ſhould not overſhade each other. On the trial, things turned out exactly as Mr. Dufay had apprehended. The lower ſurface of the loweſt pane of glaſs was firſt wetted, then the upper, then the lower ſurface of the pane above it; and ſo on, till all the pieces were wetted to the top. Hence it appeared to him, that the dew conſiſted of the vapors aſcending from the earth during the night-time; which being condenſed by the coldneſs of the atmoſphere, are prevented from being diſſipated, as in the day-time, by the ſun's heat.

M. Muſchenbroek, who embraced the contrary opinion, thought he had invalidated all M. Dufay's proofs, by repeating his experiments with the ſame ſucceſs, on a plane covered with ſheet lead. But to this Dufay replied, that there was no occaſion to ſuppoſe the vapor to riſe through the lead, nor from that very ſpot; but that, as it aroſe from the adjoining, open ground, the continual fluctuation of the air could not but ſpread it abroad, and carry it thither in its aſcent.

Water forming dew, is ſo extremely foul, as to contain from 18 to 140 grains of reſiduum in the Engliſh gallon: if expoſed to the ſun for a few days it putrifies, and ſends forth a nauſeous ſmell, by being ſtrongly impregnated with animal and vegetable extract; hence dew, the richeſt fluid applied to plants, which fact is remarkable in warm climes, when without rain, vegetation is luxuriantly carried on by means of it alone, and withal good crops are obtained.

II. Terreſtrial Waters.

ALL theſe, it is preſumed, originate from rain, melted ſnow or hail, ſinking into the pores and cavities of the earth; and conſequently, muſt be variouſly impregnated, in their progreſs, with ſuch bodies as they are capable of diſſolving, or ſuſtaining; and will be either more vitiated by ſuch additional admixtures than in their former, atmoſpherical ſtate, or will become more light and defæcated, by paſſing through ſtrata of a different kind and texture, which rather contribute to remove any impure materials than ſupply them.

SPRINGS.

AS to the origin of fountains, the full conſideration of, would open to our views a field of curious ſpeculation; accordingly, this has been a ſubject much agitated and controverted in all ages.

The moſt antient hypotheſis was delivered by Ariſtotle, who deduces, that ſprings are derived from vapors condenſed in ſubterraneous cavities. Deſcartes, with other naturaliſts, have immediate recurrence to the ocean, and on the ſuppoſition of an under-ground laboratory, aſſociate to themſelves the idea of hollow rocks receiving the watry vapors raiſed from channels connected with the ſea, by means of an internal fire; and hence, by a ſort of diſtillation, anſwering the end of alembics, in freeing the vapors from their ſaline particles, as well as condenſing and converting them into water. Lord Stairs laboured to enforce this doctrine, ſo late as the year 1741, in his Phyſico Novo; and Mr. Hume of Dantzick, ſince revived it. From what was formerly remarked, it however, appears ſuffieiently evident, that we have no ſubſtantial reaſons for believing the exiſtence of internal heat in the bowels of the earth.

Dr. Plot, in his treatiſe De Origine Fontium, is ever anxious in ſearch of ſubterranean communications between the ſea and the ſources of fountains, rivers, and the larger ſprings; and further aſſerts, that there are certain apertures which ſwallow the ſea for this purpoſe. Dr. Woodward is ſtruck with an abyſs of water towards the center of the earth; but of ſuch, we equally have no evidence to go upon. Dr. Derham again refers the ſource of ſprings to the percolation of water from the ocean; and the ſame notion is entertained by others, in modern times, tho' not that, I apprehend, it has met with countenance from facts and obſervation: on the contrary, we could mention ſome circumſtances which evince the impoſſibility of it. For example, at Bermudas, if they dig on the ſandy beach, they trace freſh water until they come to the level of the ſea, when it immediately becomes ſalt. We hear of the like occurrences at the Madeira, as alſo in other iſlands of the Eaſt-Indian ſea; and theſe imply a ſort of conviction, that the waters of the ocean do not, in fact, elevate themſelves after the manner above deſcribed.

The nature of the aſcent, is reputed to be the ſame with that of the aſcent of liquids in capillary tubes, or between contiguous planes, or in a tube filled with ſand; all which are now uſually explained upon the principles of attraction. However, ſince capillary attraction, comparatively ſpeaking, extends to no height, ſo I perceive an unſurmountable obſtacle in the way, when attempting to illuſtrate by what power, water, in direct oppoſition to its own gravity, arrives near the ſummits of mountains, where ſprings frequently abound; it being repugnant to the laws of hydroſtatics, that a fluid ſhould riſe in a tube above the level of its ſurface: not to mention, that the moſt copious fountains are connected with the higheſt grounds *, and even thoſe moſt remote from the ſea.

Meſſrs. Mariotte and Perrault aſcribe them to rain: their opinion ſimply is, that the rain-water penetrates the earth, until ſuch time as it falls in with a clayey ſtratum; which proving a ſufficient ſolid bottom to ſuſtain and interrupt its deſcent, it glides along it, in that direction to which the earth declines, till meeting with an aperture on the ſurface, it effects its eſcape, and forms the head of a river.

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* In all low and ſmall iſlands, there is always a great ſcarcity of ſprings; and, if any are found, they run only a ſmall quantity of water; but in iſlands with high lands, the ſprings are numerous, and they have running ſtreams in abundance, as in the iſland of St. Helena, which conſiſts of a rock of between two and three thouſand feet high. St. Kilda alſo is a high rock, of courſe, has a good ſupply of ſpring water.

In contradiction to them, De la Hire poſitively aſſerts, that rain never penetrates the earth, beyond 16 inches. But we are certain, that when rain falls on gravelly lands, it is occaſionally diſcoverable at far greater depths. So Dr. Walker, of Edinburgh, the profeſſor of Natural Hiſtory, found a conſiderable increaſe of water from the roofs and walls, after a ſingle day's rain, at 70 fathoms under ground, and he ſaw it diminiſh, after two or three days of dry weather. In another mine, examined by him, the water deſcended 600 feet, from a rain of nine hours continuance. Beſides, miners perfectly well know, that all the waters in mines and levels, proceed from the walls and roofs; upon ſeeing that wherever there happens to be an incurvation of the ſtratum of earth, the water iſſues always from the *ſuperior ſide*, and that none riſes, which behoved to be the caſe, agreeable to De la Hire's conception of things.

At length, Dr. Halley's ſyſtem ſeems to have given the moſt general ſatisfaction. His aſtronomical obſervations, made on the iſland of St. Helena, in 1692, furniſh forcible arguments for ſuppoſing, that ſprings originate with vapors raiſed by the action of the ſun, and by the agitation of winds, from the ſea, lakes, rivers, &c. He had recourſe to ſeveral experiments, in order to demonſtrate, that theſe are, of themſelves, an adequate fund for the ſupport of our terreſtrial waters.

Nevertheleſs, all that can be advanced in behalf of the theories of Mariotte and Halley, reſpecting rain and vapor, it muſt be confeſſed, they are ſtill encumbered with ſome difficulties. The perpetuity of many ſprings, always yielding the ſame quantity of water, when the leaſt rain or vapor is afforded, as well as the greateſt, is a powerful objection againſt each. Dr. Derham records a ſpring at Upminſter, which he could never perceive, by his eye, to be diminiſhed in the greateſt droughts, even when all the ponds in the country, had been dry for ſeveral months together; nor yet ever to augment, in the moſt rainy ſeaſons, excepting, perhaps, for a few hours, from ſudden and violent rains. The Doctor, therefore, fairly enough concludes, that had this ſpring its origin from rain or vapor, there would be an apparent increaſe, or decreaſe, of its water, correſponding to thoſe of its cauſes. Still, upon the whole, I cannot avoid hazarding the conjecture, that rain, dew, hail and ſnow, ſupply ſufficient humidity to the earth for all neceſſary moiſture.

To make a proper choice of ſpring-waters, Hippocrates earneſtly adviſes, a regard to be had to the preciſe ſituation with reſpect to the ſun, from a preſumption, at leaſt, of the ſuperior excellence of ſuch ſprings as command an eaſtern proſpect. Thoſe, looking ſome few degrees towards the ſouth, but ſtill more to the eaſtward, are claſſed next in order. Thoſe fronting nearly weſtward, with a little declination to the ſouth, he gives a third place to: whilſt ſprings, having a northern view, are ranked laſt; though a full ſoutherly poſition, is deemed worſt of all.

Dr. Percival apprehends, there is no ſolid foundation for this opinion; from perceiving water, when flowing over beds of minerals, of marle, or of black mould, to be equally bad, in whatever expoſure it firſt breaks out. But again, ſays Dr. Falconer, it can be urged in ſupport of, that the ſoil on the ſurface of the earth correſponds with the different expoſures; and, beſides, mineralogiſts know, that even the mineral ſtrata underneath, follow particular aſpects. Hence, what Hippocrates inculcates, ſeems reconcileable to reaſon as well as experience: ſince the ſubterranean water, in circulating under-ground, obſerves the direction of the ſtrata; and, therefore, will differ in its nature, according to the various ſubſtances through which it takes its courſe.

The beſt ſprings evidently flow out of a gravel, white ſand, or light and porous ſtones; I would explain this, upon the ſuppoſition that theſe firm bodies, by having an irregular figure, allow of ſome little interſtice between each; and thus conſtituting exquiſite, fine ſtrainers, can ſeparate and depoſite ſuch heterogeneous particles as are ſuſpended in the water. For the like reaſon, ſprings iſſuing from rocky ſituations, in my way of thinking, approach in goodneſs to the above, though by their connection with hilly and mineral countries, have been accounted bad, by Hippocrates and Hoffman. The ſpring at Gibraltar, is a noted example of the purity of rock-water; beſides, to quote Haller, "Ejuſmodi aqua hic rupe ex leni clivo, ſed altis marmoris rupibus ſubjecto, longa ſerie, ipſo in prædio noſtro profluunt, centum ſcaturiginibus immutabilis bonitatis *." And I might, of my own accord, adduce many inſtances of the ſort.

Springs more immediately coming off from chalky and argillaceous grounds, are hard, and extremely ill calculated for the purpoſes of life. As alſo happens to be the caſe with ſprings, when produced from mines of coal, metal, ſulphur and

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* Phyſiologia, vol. vi. p. 228.

allum. Such as run through marſhy countries, or deep beds of black mould; and other near to the ſea, we could, with equal juſtice, exclaim againſt: the latter, upon chemical analyſis, diſcover marine ſalt, and are often brackiſh, as from experiment and obſervation, I prove, to be no unuſual occurrence to the waters, in and about the town of Newport.

Springs commonly contain from five to forty grains of earthy reſiduum, in an Engliſh gallon; and hot ſprings are ſo impure, as to afford from forty to three hundred and ſixteen grains, in the ſame quantity.

Pump-water, by its ſtagnation, and want of acceſs to the ſun and air, ſuſpends a ſomewhat greater portion of earth, and neceſſarily becomes harder, than ſuch as paſſes off in more continued currents *. The rods of the piſtons impart to it an irony taſte, which, though diſagreeable, is yet harmleſs. Likewiſe, by its partial communication, as it may be ſaid, with the atmoſphere; it not unfrequently, in large cities, imbibes putrefactive ſubſtances; ſo I ſee no difficulty to account for Margraaf's obtaining nitre from the waters of Berlin; or for Dr. Heberden's detecting volatile alkali, and the nitrous and muriatic acids, in the London pump-waters *.

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* Dr. Percival chemically examined near 30 different pump-waters, and found them all hard. This leads me to mention a curious fact, relating to hard waters; which is, that ſoft ſprings have become hard, by being ſhut up for a time, by a cloſe pump-covering: probably, the water, when expoſed to the ſun and air, depoſites its terreſtrial contents.

Agreeable to the experiments of Dr. Lucas, a pint of theſe waters, gave near 12 grains of ſolid materials: a quantity rather more than Dr. Heberden found in thoſe he examined.

River-water †, if compoſed, as is conceived, of collected ſprings, and rivulets, one would expect, in point of quality, to participate a good deal of its primitive ſource; but it is generally far better adapted for œconomical uſes, than either of theſe.

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* Medical Tranſact. vol. i. p. 3.

† Although we ſhould, in ſome reſpects, remain ignorant as to the production of rivers, yet the laws of their motion, and the nature of their currents, have been explained in a moſt philoſophical manner. See an elaborate Treatiſe on the ſubject, by Mr. Mann, who has properly availed himſelf of the obſervations of Guglielmini, and other writers, in the Philoſophical Tranſactions, vol. lxix. part ii. art. 37.

Nevertheleſs, Newmann deduces, that all rivers are ſubject to gain fœculencies in their progreſs, from the filth thrown out by manufactures and populous towns, as well as from the depoſitions along their channels. And Hoffman has it, that they grow more impure, in proportion to their augmentation and extent; and erroneouſly enough ſurmiſes, that a conſiderable ſhare of what forms the wholeſome and volatile parts of the water, exhales by this means. But theſe philoſophers overlooked an additional, if I may not preſume to think, the principal ſupply: I allude to the rain brought into the channels, along the ſurface of the earth: ſuch, by having no mineral impregnation, muſt ſoften and purify the river-water, which, however, is rendered ſalubrious upon other principles. So the Ganges *, the Rhone, and the Rhine, by traverſing

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* The Gentoos are perſuaded, it poſſeſſes the ſacred virtues of purifying thoſe who bathe therein, from all pollutions and ſins; and is admired by the Indians, not only for the ſweetneſs of its ſtream, but alſo for a ſuppoſed ſanctity in its waters; accordingly, is viſited annually by hundreds of pilgrims, who pay their devotions to it, as if to the Deity. The ancient poets and painters repreſent the deities of ſprings and rivers, as combing, or carding their waters: they likewiſe paint them, as holding an inclined arm, or veſſel, out of which the water conſtantly pours. Hence Virgil——

Pocula ſunt fontes liquidi, aut exercita curſu Flumina.

verſing over vaſt tracts of countries, have been reputed the beſt rivers in the world. To the ſame cauſe, Proſper Alpinus * attributes, in a great meaſure, the ſuperior excellence of the Nile, which takes its riſe nearly under the tropic of Capricorn, and after running through the whole breadth of the torrid zone, empties itſelf into the Mediterranean, in the latitude of about 32 deg. north. Thus, theſe rivers, by their rapid motion, and by being expoſed, during a long and hot courſe, to the influence of the ſun and air, are in a manner depurated, and cleared of all impurities.

I avoid fixing, with preciſion, the ſtandard proportion of heterogeneous matters contained in a definite quantity of river-water, as it is ſo varied by floods, tides, and other accidental circumſtances.

A gallon of bright Thames-water, of a few days ſtanding, on evaporation, yielded 31 grs. 452 thouſandth-parts of a browniſh ſediment, which, on applying afterwards to heated iron, was reduced to 22 grs. 6 hundredth-parts, conſiſting of only 15 grs. one-half of calcareous earth, with about 6 grs. one-half of muriatic and nitrous ſalt.

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* Mid. Egypt. lib. i. cap. 10.

A pint of the water of the river Rhine, according to Haller, afforded but one grain and a quarter of ſolid contents; and the water of the New River, in London, leſs than one grain, in the ſame quantity. Dr. Haygarth at Cheſter, evaporated to dryneſs, by a gentle heat, not exceeding 100 deg. ſeveral kinds of water, and had, out of a gallon of the Dee water, a reſiduum of ſeven grains; a favorite ſpring, called barrel-water, 15 grains; and, of each of the other ſprings, from 60 to 80 grains.

Stagnant water, ſuch as that of lakes, ponds, marſhes, pits and ditches. Of all other waters, this is apparently moſt diſguſtful to our ſenſes; ſince herein millions of little reptiles breed and engender, and the whole teems with ſhapeleſs life, Beſides, it often contracts a diſagreeable taſte, from leaves, and other vegetable ſubſtances, left to corrupt in it. Its bad effects in drink are well deſcribed by Hippocrates. Quæcunque (Aquæ) igitur paluſtres ſunt, et ſtabiles, et lacuſtres, eas neceſſe eſt æſtate eſſe calidas, ac craſſas, et olentes, Quum enim non defluant, ſed Aqua pluvia ſemper nova inferatur, et ſol urat; neceſſe eſt, ipſas decolores eſſe, et pravas, et bilioſas. Hyeme vero glaciatas, et frigidas, ac turbatas præ nive et glaciæ ut pituitoſſimæ ac raucoſiſſimæ exiſtunt, Bibentibus autem ſplenes ſemper ſunt magni ac pleni, et ventres duri, tenues, et calidi. Humeri vero, et claviculæ, et facies attenuata. In ſplenum enim carnes colliquantur quapropter graciles exiſtunt *. Aretæus, long ago, conſidered ſuch waters as productive of viſceral obſtructions; and mentions another complaint, very prevalent in Egypt, bearing reſemblance to the ulcerated ſorethroat, proceeding from drinking the corrupt and ſtagnant water of the Nile. Haller cautions us, in the ſtrongeſt terms, againſt their uſe. Poſſes addere ad Aquas potiſſimum paluſtres et pluviatiles tenuiſſima effluvia putrilaginoſa plantarum et cadaverum. Ex utriſque dyſenteriam Aquæ de ſequana hauſtæ deducunt ex iſtis dyſenterias pannonicas ſubitaſque nonnunquam mortes †. And let it be remembered, that, in hot climates, fevers and fluxes are conſtantly induced by this evil; and, on the coaſt of Guinea, where the waters are exceſſively bad, the ſcurvy, ſwelled and ulcerated legs, with worms in them, become the common fate of Europeans, whoſe deſtiny leads them to that inhoſpitable ſhore.

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* Hippocrates de Aëre, Aquis, et Locis.

† Haller. Phyſ. vol. vi. p. 236.

The Correction of Waters.

WHOLESOME water, in ſufficient plenty, as one of the moſt indiſpenſible neceſſaries to the animal world, promiſes the greateſt advantages to any habitable ſpot: whilſt, on the other hand, the ſcarcity, or badneſs of this article, expoſes us to numberleſs inconveniences; and, therefore, wherever Nature hath denied the benefit of pure water, it makes an object, of the firſt importance, to be able to avail ourſelves of ſome methods of correcting its pernicious qualities.

Common water manifeſtly ſuffers annoyance from different cauſes, and theſe totally dependent upon its ſeveral native or accidental impregnations. To its terreſtrial, aërial, and ſaline contents, beyond certain limits, we owe that well-known property, named Hardneſs; and, as was ſpoken of before, the extractive matters of animals and vegetables, cannot fail, ſooner or later, to impart to it a degree of putrefaction.

In treating of the earthy ſubſtances occaſioning hardneſs, I have to confine my views to the calcareous and ſelenitical; the other ſimple earths, being only diffuſed, or lightly ſuſpended in water. The firſt ſpecies is found in extenſive ſtrata, and has been held among the moſt abundant productions of Nature. It exiſts in a variety of ſtates, as lime-ſtone, marle, and chalk, which differ only in purity, or mode of connection.

Scarce any waters are, perhaps, altogether deſtitute of ſuch admixture, but they often contain it in large proportions *; and philoſophers were at a loſs to explain the reaſon, until the experiments of Meſſrs. Cavendiſh and Lane taught them, that the ſolution was accompliſhed by virtue of fixed air: it giving to the water, the powers of a menſtruum with reſpect to the earth, which is inſtantly depoſited, upon the evaporation, or flight, of this ſame principle. In the temperature of 60 deg. calcareous earth requires about 680 times its weight

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* We have a number of theſe ſprings all over England, bearing the name of petrifying waters; and, when natural hiſtory was leſs enlightened, they ſtruck the vulgar with aſtoniſhment. We read of a curious inſtance, among others, of a foſſil marle produced out of a water, at Newton Dale; the calcareous matter here carried down by the ſtream, furniſhes lime-ſtone and marle enough to ſupply the country around; but the quantity precipitated is ſmall at the ſource of the ſpring, and the petrifying quality gradually loſt, as the waters flow along.

See *Martial's Rural Oeconomy of Yorkſhire.*

weight of water to diſſolve it. The vitriolic acid alſo ſuſpends calcareous earth in water, under the form of an inſipid concrete, called ſelenite, or gypſum; conſiſting of about 30 *per cent.* of acid, 32 of mere earth, and 38 of water. This no unfrequent impregnation, and, like the former, always poſſeſſes the property of rendering water hard and unfit for œcumenical uſes.

Selenite has a peculiar, ſub-acid taſte, which it communicates to water, cauſing withal an evident ſenſation of cold and weight in the ſtomach and bowels. This ſame ſenſation, however, is certainly more owing to the diſagreeable impreſſion on the nerves, or to other qualities in the waters, than to their real weight; on which account, the ancients named ſuch waters crude, and indigeſtible, in oppoſition to ſuch as were more grateful to the ſtomach. The formation of ſtalactites, or the large, columnar maſſes, met with hanging to the roofs of caves, proceed from the gradual dropping of theſe waters. And gypſum often fills up the fiſſures of mountains, abounding in ores of metals. According to Kirwan, and the chemiſts of Dijon, it is ſoluble in about 500 times its weight of water, at the temperature of 60 deg.

If we deſire to aſcertain the preſence of calcareous earth in water, either in a ſimple or compounded ſtate, we employ the ſaccharine acid; it being ſo delicate a teſt, ſays Bergman, as to exhibit white clouds and ſtriæ, if but a ſingle grain of pure lime be diſſolved in a kanne of diſtilled water. In the inſtance of gypſum in water, the new acid, from its ſtronger attraction for the earthy baſis, ſeizes upon it, and thus, by forming an inſoluble compound *, precipitates, in the mean while, the vitriolic acid is forſaken. The pureſt water, as that of ſnow for example, will indeed, by means of this re-agent, yield a portion of ſaccharated lime †,

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* The ſaccharine acid attracts lime with ſuch force, that it ſeparates it from every other: this combination, therefore, cannot be decompoſed by any acid, alkali or earth, hitherto known, and can only be decompoſed by fire. *Bergman.*

† Eighty-two parts of ſaccharine acid take up 100 of pellucid, calcareous ſpar, but not immediately; becauſe the ſurface, when ſaturated with the acid, prevents the acceſs of the acid to the internal nucleus. Nitrated lime is completely precipitated by acid of ſugar, in the form of a white powder, not ſoluble in water; of 119 parts, by weight, of this powder, 72 fall to the bottom, and 47 are procured on evaporation; hence it appears, that 100 parts contain of acid 48, of pure lime 46, and of water, 6; ſo that, not only the preſence of lime in water is diſcovered by acid of ſugar, but even its quantity may, without difficulty, be aſcertained. *Bergman's Eſſays.*

although ſometimes ſo ſparingly as to elude obſervation, unleſs lines are drawn on the bottom of the veſſel, with a glaſs rod. A combination of the acid of ſugar with alkaline ſalt, anſwers ſtill better, in conſequence of a double affinity.

As other cauſes of the hardneſs of common water, I could mention the ſaline matters, and the uncombined acids, whether mineral, vegetable, or aërial; but ſince they all demand one and the ſame mode of treatment, as the calcareous and ſelenitical earths, I forbear ſaying any thing further reſpecting them.

Various contrivances have been propoſed towards remedying theſe, and other bad qualities of waters, entirely grounded on chemical and phyſical conſiderations.

Percolation alone, renders water tolerably pure, ſalutary, and potable; and wonderfully improves it for culinary purpoſes.

In the ſouthern parts of Europe, many of the inconveniences formerly recited, are obviated, if not removed, by a ſort of ſtone, termed filters, through which the liquid is allowed to paſs. But as there is a difficulty, at all times, in providing ſuch an apparatus, we would ſubſtitute the following one, as recommended by Dr. Percival.—Let a large funnel, formed out of wood, have its narrow neck filled with ſpunge; upon this is ſpread a layer of ſand and gravel, and, after covering with thick flannel, over the whole is placed another layer of ſand, leaving, however, ſufficient room for the filtration of the liquid; and care muſt be taken to renew the ſpunge and ſand as often as charged with the impurities of the water. Fine ſand is preferable to filters, as it performs the operation with more rapidity; beſides, juſt to recapitulate what was expreſſed before, when accounting for the ſuperior goodneſs of gravelly ſprings, the minute grains of ſand adapt themſelves accurately to one another, but yet, from their inequalities, do the office of ſtrainers, ſo far as to diveſt the water of its noxious and heterogeneous contents. Thus it is found, that ſea-water can, by filtering it repeatedly through freſh portions of ſand, be depurated nearly, if not altogether, of its coolneſs, ſo as to become fit for the uſe of mariners: an art long wiſhed for, and of the higheſt moment.

A Mr. Allen, of Newhaven, in America, has of late, by a very ſimple proceſs, ſucceeded beyond all expectation. He procured a common hogſhead, with a falſe bottom, about three or four inches above the level head. This falſe bottom is perforated with a number of holes, and over them is laid a filter of flannel. The barrel is then nearly filled with the fineſt ſand, beat down exceedingly hard; and a tube, communicating with the ſpace between the two bottoms, is extended to a convenient height above the top of the barrel. The ſea-water is poured into this tube, and preſſing in all directions, according to its altitude, endeavours to force its way through the ſand to the top of the barrel, from whence it is drawn off pure. The ſaline particles being heavier than thoſe of the ſand, and perhaps differently formed, are intercepted and left behind, whilſt the water is admitted. Somewhat upon the ſame principle, I would explain why freſh-water ſprings are got at within 20 yards, or leſs of the ſea, as happens at Bermudas, where they riſe and fall, with the flood and ebb; yet often there, by digging two or three feet deeper, ſalt-water iſſues forth. Furthermore, we know, that pump-water, in ſea-port towns, is much leſs brackiſh than the ſea, though evidently derived from it.

Many attempts were made for rendering *ſea-water* good and potable; but, in general, they have been little elſe than different modes of diſtillation:

though ſeveral of the authors of them, either thro' ignorance of the real nature of ſea-water, or from an artful deſign of giving their proceſs a myſterious appearance, have mixed various ſubſtances with the water, either before or after its diſtillation. The ſame method was practiſed by Sir R. Hawkins, in the reign of Queen Elizabeth [*].

Mr. Hauton had a ſecret for this purpoſe, which he at length communicated, in the Hiſtory of the Royal Academy. It conſiſted in, firſt, precipitating the water with oil of tartar per deliquium, then diſtilling, and, laſtly, filtering it through a peculiar ſort of earth, which he mixes with it, and ſuffers to ſettle to the bottom. After theſe three operations, the liquid remains perfectly ſweet, and no way diſtinguiſhable from the very pureſt rain-water [†].

Dr. Liſter propoſes the freſhening of ſea-water, by virtue of common ſea-weed, or alga marina; theſe vegetables, like all other plants, continually exhale a large quantity of water in a vaporous form; and that being all pure, he recommends, on this baſis, a diſtillation without fire, as follows:

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[*] Purchas's Collection of Voyages, book vii. chap. v.

[†] Phil. Tranſact. Abridg. vol. ii.

The body of a large ſtill, or alembic, is to be filled three parts with ſea-water; ſeveral freſh and growing ſea-plants are to be put thereinto, in their growing poſition; then, after the head is fitted on with a receiver adapted to the noſe, there will be a perpetual aſcent of vapor from the plant, which condenſes into water in the head, and this may be thence conveyed into the receiver, ſweet, clear, and in every reſpect fit for drinking. The quantity thus procured, however, though conſiderable in regard to the manner of obtaining it, can be but ſmall, in proportion to the wants of a ſhip's company *.

Another method of ſeparating ſalt from ſea-water, without fire, is noticed in the Philoſophical Tranſactions: Take a veſſel of wax, hollow within, and every way tight; plunge it into the ſea, or other ſalt-water, and there will be made ſuch a ſeparation, that the veſſel ſhall be full of ſweet water, the ſalt ſtaying behind. But although this water betrays no ſaltiſh taſte, yet a ſalt will be found in the eſſay.

The thawed ice of ſea-water is often uſed in Amſterdam for brewing: And Bartholine, in his

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* Phil. Tranſact. No. 156.

book, *De Nivis Uſu*, confirms this relation: "'Tis certain," ſays he, "that if the ice of the ſea-water be thawed, it loſes its ſaltneſs; as has been lately tried by a profeſſor in our Univerſity."

Captain Cook, in his voyage round the world, was furniſhed with freſh water, from the melting of the floating ice at ſea; and this water, we are told, was not only freſh, but ſoft and wholeſome. Mr. Barker alſo obtained, from ſalt-water, which was left to freeze, ice, that, being drained, ſeemed quite freſh *. Laſtly, Mr. Nairn, the optician, in making experiments on ſea-water, found, that after it was frozen, and the frozen ſurface removed, and ſuffered to melt, that there was not any ſaline matter to the taſte, and only a very ſmall portion diſcoverable by certain delicate teſts.

The proceſs of Mr. Appleby, publiſhed at the requeſt of the Lords of the Admiralty, in 1734, depended on mixing with twenty gallons of ſea-water, ſix ounces of a fixed alkali, prepared with quick-lime, as ſtrong as lapis infernalis, and ſix ounces of bones, calcined to whiteneſs, and finely powdered, and drawing off in a common ſtill, with a ſlow fire, fifteen gallons †. Dr. Butter preferred the uſe of ſoap-leys, to that of the lapis infernalis, and calcined bones.

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* Phil. Tranſ. vol. 66, part ii.

† Phil. Tranſ. vol. 48.

Dr. Hales propoſed a method of keeping the ſea-water cloſe ſhut up, till it putrified, and again became ſweet, and afterwards diſtilling the water; upon which he found, that three-fourths of the ſea-water were freed both of the bittern and acid. He ſubjoins a particular detail of the circumſtances which may make this operation eaſy. In another place, he directs, for this purpoſe, the uſe of powdered chalk, and ventilation, by blowing ſhowers of air up through the diſtilled water, by means of a double pair of bellows *.

Captain Chapman, in 1757, ſucceeded in obtaining a ſupply of freſh water, by diſtilling ſea-water with wood aſhes, inſtead of the ſoap-leys of Dr. Butter. In 1761, Dr. Lind diſcovered, that ſea-water diſtilled, even without the addition of any ingredients, afforded a water as pure and wholeſome as that got from the beſt of ſprings; and, in 1762, an account of the diſcovery was read to the Royal Society, and ſoon after publiſhed by authority.

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* Treatiſe on Ventilators, part ii. and Phil. Tranſ. vol. 49.

This ſame manner of procuring freſh water, has, at preſent, attained to a great degree of perfection, both in England and France. M. de Bougainville, in his voyage round the world, bears ample teſtimony, as to the utility of the machine for diſtilling ſea water, which was made public in 1763, by M. Poiſſonnier, its inventor; and Lord Mulgrave, in his voyage towards the north pole, in 1773, has done equal juſtice to the method of obtaining freſh water from the ſea by diſtillation, which was introduced into the Engliſh navy in 1770, by Dr. Irving, for which he obtained a parliamentary reward of *five thouſand pounds*.

In order to come at a clear notion of Dr. Irving's device, let us imagine a tea-kettle to be made without a ſpout, and with a hole in the lid, in the place of the knob; then the kettle being filled with *ſea-water*, the freſh vapor which ariſes from the water, as it boils, will iſſue out through the hole in the lid; into that hole, fit the mouth of a tobacco-pipe, letting the ſteam have a little inclination downwards; then will the vapor of freſh water take its courſe through the ſtem of the tube, and may be collected, by fitting a proper veſſel to its end. This would be an apt repreſentation of the Doctor's contrivance; in which he has adapted a tin, copper, or iron tube, of ſuitable dimenſions, to the lid of the common kettle, uſed for boiling the proviſions on board a ſhip; the freſh vapor, which ariſes from boiling ſea-water in the kettle, paſſes through this tube into a hogſhead, which ſerves as a receiver; and, in order that the vapor may be readily condenſed, the tube is kept cool, by being conſtantly wetted, with a mop, dipped in a tub of cold ſea-water *.

It appeared, from the evidence which was delivered to the Lords of the Admiralty, by many reſpectable officers, who were eye-witneſſes to an experiment made on board the Arrogant, at Spithead, in January, 1771, that eighty gallons of ſea-water did, in twenty-five minutes, after being put into the copper, and a fire made, diſtil in the proportion of twenty-five gallons per hour, into freſh water, perfectly well taſted, and of leſs ſpecific gravity than the beſt ſpring-water in that neighbourhood; and the ſaid officers gave it as their opinion, that five hundred gallons of freſh water, might be diſtilled, in the ſpace of twenty-

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* For a particular account of the advantages attending this method of diſtillation, contraſted againſt the defects and inconveniencies of the other methods that have been propoſed, ſee *Voyage towards the North Pole, Append. p.* 205, *&c.*

four hours, with the ſame quantity of fuel, in proportion to the time, as is required in the ordinary buſineſs of the ſhip.

Every ſhip's kettle is divided into two parts, by a partition in the middle: one of theſe parts is only in uſe when peas or oatmeal are dreſſed; but water is at the ſame time kept in the other, to preſerve its bottom. Dr. Irving availed himſelf of this circumſtance; and, by filling the ſpare part of the copper with ſea-water, and fitting on the lid and tube, he has ſhewn, that ſixty gallons of freſh water may be drawn off, during the boiling of either of the above-mentioned proviſions, without the aid of any additional fuel. He recommends, likewiſe, the preſerving of the water which may be diſtilled from the coppers in which peas, oatmeal, or pudding are dreſſed, as both a ſalutary beverage for the ſcorbutic, and the moſt proper kind of water for the boiling of ſalt proviſions: and further particularly remarks, that only three-fourths of the ſea-water ought to be diſtilled, as the water diſtilled from the remaining concentrated brine is known to have a diſguſtful taſte *.

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* See an account of ſeveral experiments made on ſome of the beſt diſtilled water, prepared by Dr. Irving from ſea-water, in Watſon's Chem. Eſſays, vol. ii.

Sea-water, at an average, taken from obſervation made in different climates, the Biſhop of Landaff ſpeaks of, as containing about one thirtieth of its weight of common ſalt. The ocean is, however, much ſtronger impregnated with ſalt towards the Equator, or as we approach the Line; and, the nearer the Poles, the weaker the impregnation.

One pound of water in the Britiſh channel, yields an ounce of ſalt; in the Baltic, two drams; and, in the Mediterranean and Spaniſh ſeas, two ounces. This has been variouſly accounted for; but I am diſpoſed to attribute the ſame to the exhalation from the ſea going on conſiderably faſter in the warmer atmoſphere than in the colder, ſo in proportion to the deſcent of rain, there is a larger quantity of ſalt left behind,

Nevertheleſs, it may be argued, that as more water evaporates, more will perpetually fall; but this does not follow, ſince the water which exhales in the warmer regions, is driven by winds into the colder; and, in conſequence of the weak attraction of the air, is no ſooner depoſited in the latter.

The hon. Mr. Boyle inſtructs us how to examine the freſhneſs of water, by means of a precipitate, which diſengages any ſaline particles floating therein. To one thouſand grains of diſtilled water, he adds a grain of ſalt; and, into the ſolution, lets fall a few drops of a ſtrong, well-filtered ſolution of refined ſilver, diſſolved in ſtrong, nitrous acid; or, in other words, a ſolution of lunar cauſtic; upon which there immediately appears a whitiſh cloud, which, though but ſlowly, deſcends to the bottom, and there ſettles in a white precipitate, in which is the ſaline matter of the liquid. This method, if it were required, would detect ſalt in water, if there was but one grain of ſalt in two thouſand, nay, in three thouſand times the weight of water; as, indeed, Mr. Boyle proved, before King Charles the Second, but was enjoined to keep it *a ſecret* *.

The hardeſt water ſoftens by the addition of ſalt of tartar; but often ſuch a quantity of the vegetable alkali is neceſſary to produce the effect, as to give an offenſive flavor to the palate. On adding, by little and little, a ſolution of this ſalt, the water grows more and more turbid, until the acid, completely neutralized by the alkali, parts with all the earth, which, on ſtanding, ſettles to the bottom. And, in order to determine the exact proportion of ſalt any given water requires, we have only to advert to the precipitation in the mixture, and weigh the alkaline ſolution, previous to the experiment. The water thus corrected, though really no purer than before, is, notwithſtanding, made perfectly ſoft, and far leſs, if at all, detrimental to health.

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* Vide Uſefulneſs of Experimental Philoſophy, by Boyle.

Ebulition promotes the depuration of water; and, ſurpriſing it is, that this precept, ſo univerſally inculcated by the ancients, ſhould, in modern days, have been ſo much abandoned. For, although heat increaſes the diſſolving power of any menſtruum, it tends, at the ſame time, on many occaſions, to deſtroy the texture, and diſunite the component parts of the ſolvend.

The aërial acid is expelled, in a very moderate degree of heat, that whenever the ſolid matters are ſuſpended by means of it, the water ſoftens without difficulty; but again, if the hardneſs proceeds, as it more uſually does, from the intimate combination of earth with either of the mineral acids, coction alone, yet ever ſo long perſevered in, will, I am perſwaded, anſwer no good end; and therefore, in the latter inſtance, would adviſe adding a ſmall portion of ſalt of tartar to the boiling water, which, after decantation, and expoſure to the air, may be drank with ſafety.

Water, from being often the repoſitory of minute animals, or vegetable ſubſtances, and by its ſtagnation, is, as was mentioned before, diſpoſed to putrefaction; and, whilſt thus degenerated, proves exceedingly injurious to health, if not fatal*. Such changes are not unfrequent to the Thames-water; which, on carrying to ſea, and eſpecially into a warmer climate, has, in the ſpace of eight days, acquired an intolerable ſtench: and ſeamen aſſure us, that water generally corrupts twice, if not thrice, in a long voyage. For, in about a month after exportation, when the bung is taken out of the caſk, the water ſends up a noiſome and dangerous vapor, which readily takes fire, on the application of a candle: the volatile alkali, in this inſtance, eſcapes; hence the water becomes pure.

Under an idea of removing this ſame noxious quality of water, ſeveral proceſſes have been ſet on foot *. Beſides boiling, decanting, and percolation after the manner already deſcribed, recourſe is here had to other modes of refinement. By agitating the liquid in mills, and cauſing it to paſs through the atmoſphere in the form of jets, caſcades, &c. we free it of the putrid, volatile particles. But ventilation is ſucceſsfully practiſed on a board ſhip, by means of Oſbridge's machine; and, at many of our ſea-port towns, very cheap and commodious ventilators are ſold for this purpoſe; conſiſting of only a pair of bellows going into a thin tube, with a head full of holes, like that of a watering pot; which tube being put to the bottom of a jar, or pail of foul water, and freſh air blown through it, the water becomes ſweet and good in a ſhort time. The addition, likewiſe, of a ſmall quantity of ſpirit of vitriol, or of unſlacked lime, effectually preſerves water from the putrefactive fermentation.

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* Experience evinces, that if cows drink fœtid water, their milk and butter diſcover a bad taſte; and this plainly ſhews, that the water retains its putrid quality, when mixed with the blood. *Phil. Tranſ. vol.* 49.

To this effect, a method of ſecuring water from putrefaction, was, ſome years ſince, inculcated by Dr. Alſton. It conſiſted, in adding a quantity of lime to every caſk of water; and, as lime is known

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* As to the methods of purifying water, there are full and ſatisfactory accounts in Dr. Lind, and Dr. Alſton's, publications on the ſubject.

to have a ſtrong, antiſeptic property, water, ſo long as it retains the impregnation of lime, never putrifies. In order to free the water, at the time of uſing it, from the lime, the Doctor propoſed the precipitation of the latter, by throwing in a quantity of magneſia alba, on this principle; that, as lime-ſtone is rendered ſoluble in water, by the deprivation of its fixed air, and has a greater affinity with that air than magneſia has, the particles of quick lime diſſolved in the water, would attract the air from the magneſia, and thereby becoming no longer ſoluble, would fall to the bottom, and leave the water taſteleſs, and fit for œconomical uſes *.

The expence, however, attending this proceſs, oppoſed the execution of this propoſal. Mr. Henry,

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* Dr. Black proved, that magneſia was precipitated from acids by volatile alkali; if uncalcined, however, it precipitated calcareous earth from acids; but, when calcined, or in other way deprived of its gas, it did not precipitate theſe earths: when uncalcined, united with gas, it precipitated lime from lime-water; which ſhews, that the calcareous earth had a ſtronger power to combine with the gas than the magneſia had, ſince the former earth derived this gas from the latter; by which means the former was rendered mild and unſoluble in water, and therefore was precipitated. This property put Dr. Alſton upon a method of procuring ſweet water at ſea, by adding magneſia to water, the putrefaction of which had been prevented, by the previous addition of quick lime.

of Mancheſter, has ſince ſuggeſted a cheap and eaſily practicable method of precipitating the lime, and thus of reſtoring the lime to its original taſte.

The following is a conciſe ſtate of his proceſs.— To preſerve the water from putrefaction, two pounds of good quick lime are directed to be added to each caſk of water of a hundred and twenty gallons. To free the water, afterwards, from the lime with which it has been impregnated, it is to be drawn off into a ſtrong caſk, containing about 60 gallons; with an aperture at one end, large enough to admit a veſſel, which is to be let down into it by means of ſtrings, and which holds a proper quantity of effervеſcent materials; that is, if marble or chalk, and vitriolic acid. Eight ounces of mild, calcareous earth, and ſix ounces of ſtrong, vitriolic acid, will be ſufficient for ſixty gallons of lime-water. The mouth of this laſt veſſel is to be cloſed with a tubulated ſtopper, through which the fixed air, let looſe from the marble, paſſes up through the body of the water. The lime is thus rendered inſoluble, and is ſoon precipitated in the form of an impalpable powder of chalk; the water being thus reſtored to the ſame ſtate of purity, as when it was firſt ſhipped on board; or, as Mr. Henry believes, to a ſtate of ſtill greater purity;

ſeveral hard waters having, in conſequence of this ſame proceſs, been made as ſoft as rain-water, and freed from different impregnations *.

I am now about to ſuggeſt a few prudent cautions relative to certain metallic impregnations, ſince all the acids act more or leſs forcibly upon lead and copper, and thus, occaſionally, communicate to water the moſt deleterious properties.

The water with which large towns are ſupplied, is chiefly brought from rivers and ſprings at a diſtance, by leaden pipes, and depoſited in ciſterns of the ſame metal; but, for the reaſon juſt aſſigned, both Hippocrates and Galen condemn this practice; and Vitruvius, the Roman architect, remonſtrates ſtrongly againſt it. Multo ſalubrior ex tubulis Aqua quam per fiſtulas: quod per plumbum videtur eſſe ideo vitioſa, quod ex eo ceruſſa naſcetur: hæc autem dicitur nocens eſſe corporibus humanis. Itaque minime fiſtulis plumbeis Aqua duci videtur, ſi volumus eam habere ſalubrem †.

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* For further particulars, and the deſcription and drawing of an apparatus for this operation, ſee Henry's Account of a Method of Preſerving Water at Sea, &c.

† Vitruvius's Treatiſe on Architecture, lib. viii. c. 7.

Yet, were we to rely ſolely on the experiments of Dr. Hales, Dr. Baker, and Dr. Percival, it will not appear that lead, by mere immerſion in water, imparts any thing noxious to it; and, conſequently, leaden pipes muſt, in that reſpect, prove innocent. But negative evidence of this kind is weak, when ſet in oppoſition to obſervation and matter of fact.

Newman, whoſe authority as a chemiſt is of great weight, delivers it as his opinion, that the waters, conveyed by pipes, may contract diſagreeable qualities; and he aſſures us, that, on examining the aqueducts at Rome, thoſe between Marly and Verſailles in France, and thoſe of London, he found them covered with a whitiſh cruſt, or ceruſe, which, doubtleſs, proceeded from the action of the different ſubſtances contained in the water, on the metal. The experiments of Dr. Heberden, likewiſe ſhew, that lead, by long ſtanding in common water, is converted into a calx, ſimilar to what is formed by its union with acids.

When waters are kept in open reſervoirs, they are ſubject to be tainted with animal and vegetable extracts, and theſe operate as ſolvents upon metallic bodies. This is confirmed, in the account given by Dr. Tronchin, of the famous colic of Amſterdam,

dam, the cauſe of which had ſo long eluded the reſearches of the learned; until, at length, it was diſcovered to be produced by the uſe of rain-water, which had imbibed the vegetable acid from the leaves of trees blown by the wind upon the leaden roofs of the buildings, and ſo diſſolving the metal. Moreover, in open veſſels, the lead, by the riſing and falling of the water, is expoſed to the alternate action of the air and moiſture, whoſe powerful effects alone, in corroding metals, are but too fully determined. The Baron Van Swieten relates, "Vidi integram familiam hoc morbo (ſcilicet Colica Pictonum) laboraſſe, dum ad culinares uſus adhibebatur aqua, in magno receptaculo plumbeo collecta, et diu hærens."

Water frequently contains one or other of the mineral acids, in a compounded ſtate; as that of nitre, ſea-ſalt, and gypſum: but we have too the vitriolic acid, combined with the argillous and aluminous earths *; and thus it is Dr. Percival ingeniouſly hints at the impropriety of lining wells and ciſterns with brick and terras, as is the caſe in the

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* For a more particular account of the methods by which this metal gains admiſſion into our food, ſee Dr. Baker's papers in the firſt and ſecond volume of the Medical Tranſactions, and Dr. Percival's elegant work, on the ſame ſubject.

north of England, where natural ſprings are very ſcarce *.

Water, when infected with this dangerous mineral, is hardly ſenſible to the taſte; and if at all ſo, rather pleaſant than otherwiſe; and its conſequences are manifeſt in the ſtomach and inteſtines, whoſe nerves it irritates, cauſing vomitings, violent colics, convulſions, ſtupor and palſy, withal characteriſed by the flatneſs of the belly, and ſinking of the navel.

Antimonial emetics and purges have been adminiſtered, with ſucceſs, in ſuch caſes. Navier adviſes, the different livers of ſulphur, and the hepatiſated waters.

The volatile tincture of ſulphur is eſteemed the niceſt re-agent for diſcovering lead in water, though we dare not always ſpeak as to its infallibility; ſince a portion of the metal, too ſmall to be detected, on chemical examination, may be ſuſpended in ſolution, which yet will, in irritable habits, and under certain circumſtances, prove highly injurious to the conſtitution.

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* Martial's Rural Oeconomy of Yorkſhire.

A cupreous impregnation, in like manner, often occurs from the veſſels employed in culinary operations; and particularly where the vegetable acid is concerned, as in pickles, ſweetmeats, &c. *

The volatile alkali, if, by accident, it falls in the way of this metal, is, however, of more conſequence. The propereſt remedies in the inſtance of poiſoning by copper reduced into verdigris, are emetics, abundance of water, liver of ſulphur, and alkalies.

The volatile alkali betrays the preſence of copper, by giving to the water, a fine, blue tinge: although, ſhould there only be diſſolved one hundredth part of a grain in a pint of the liquid. Nevertheleſs, the phlogiſticated alkali is ſtill more accurate, and precipitates the metal of a bright, copper colour, with an increaſe of weight, as Mr. Macquer firſt demonſtrated: perhaps, it is really metallic copper, the calx having received enough of phlogiſton from the alkali, to be revived.

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* See a treatiſe entitled, Obſervations and Experiments on the Poiſon of Copper, by the ingenious Dr. Falconer of Bath. Alſo, Blizard's Eſſay on Bell-metal Mortars and Pewter Veſſels.

The more obvious Characters of SALUBRIOUS WATER.

WE judge of the purity of water in general, from obſervation of its ſenſible qualities. When good, it is conſtantly limpid and colourleſs; eſſential ſoever as theſe properties would ſeem, it does not invariably follow, that ſuch waters are pure, ſince moſt look beautiful to the eye on bare inſpection, whilſt often fœtid to the utmoſt degree, or much impregnated with terreſtrious particles; ſo, in fact, ſea-water excells every other in tranſparency.

Its being inodorous is another teſt, not leſs dubious than the former; as few ſprings, however impure, give out ſmell; nor more do the waters of rivers and ponds, except in a ſtate of putrefaction.

Others regard its inſipidity; but, as the ſenſe of taſte varies ſo much in different perſons, this is not to be entirely depended on in any caſe; and in ſome, it is liable to great miſtakes, for ſeveral of the ſaline and earthy ſubſtances, diluted as they commonly are in ſprings, have little or no diſtinguiſhing flavor.

The ſpecific gravity lays, in ſome meaſure, a foundation towards proving the goodneſs of waters, and unqueſtionably with reſpect to the terreſtrial ones, the fewer diſſolutions floating in them, the lighter and better they are; but again, this mode of enquiry cannot ſo aptly apply to the atmoſpherical waters, whoſe volatile contents do barely contribute to their gravity. Beſides, water is liable to be rarefied, and of courſe rendered lighter by different degrees of heat, ſo it is difficult to fix a ſtandard of its real weight. The moſt approved method is, by comparing the gravity of the beſt common, cold water with the more fixed and immutable weight of any other body, particularly gold, whoſe ſpecific gravity has been eſtimated to that of water, as 4,907 to 250, almoſt as 20 to 1.

Likewiſe, for determining this point, an hydroſtatical balance, and a good aerometer are peculiarly convenient; but, if theſe inſtruments are not to be had, an ordinary balance may be ſo managed, as to compare the weight of diſtilled, or very pure ſnow-water, with that of other waters; this is done by means of a glaſs veſſel with a narrow neck, which is to be filled with water to a certain mark, and exactly weighed. Hoffman, in ſeveral curious experiments, examined hydroſtatically by the aſſiſtance of a glaſs water-poiſe divided by lines, the various kinds of water, and found that the increaſing difference from the pureſt of all to that of turbid, ſtagnating, ditch-water, was from 1 to 7 lines in the ſcale, which, in the extreme, is that of eight grains.

According to Haller, well-water is, in weight, to rain-water, as 740 to 733, or about 104th part heavier. By Dr. Lewis's account, rain-water is 50 grains, and ſpring-water 82 grains, in the pint, heavier than diſtilled water. Whereas Dr. Falconer, whoſe accuracy will not be diſputed, repeated theſe trials with diſtilled water of his own preparing, and never perceived rain-water to exceed diſtilled water above one tenth of that weight, or five grains in a pint; and no ſpring-water to exceed diſtilled water above 25 grains in weight, in the ſame quantity.

Another criterion we go by, in order to aſcertain the purity of water, is its ſoftneſs. This quality, of all others, claims our earneſt attention; as without it, water would be totally unfit for moſt purpoſes of life.

From a compariſon of different waters, naturaliſts reckon ſuch ſoft and good, as contain leſs than ten grains of ſolid materials in the pound weight. But, provided they ſuſpend that quantity, or beyond, they are deemed hard.

Agreeable to Dr. Haller, waters may, in general, be accounted ſoft, if leaving, on evaporation, not above five grains of ſediment in a pint: whilſt thoſe, on the contrary, are hard, if yielding from five to fifteen grains, in the ſame proportion, which probably is as much as moſt waters afford.

The diſcrimination between hard and ſoft water, is even diſcoverable to the tangible hand, in the inſtance of ſimple ablution; as alſo, from its difficult, or eaſy union, with ſaponaceous matters. For the like reaſon, ſoft water diſſolves ſoap readily, and forms with it an homogeneous liquid; whereas, ſuch as is hard, curdles the ſame, becauſe, the alkali of the ſoap, by attaching itſelf to the acid of the ſelenites, diſlodges the oil, and allows it to riſe to the top. Therefore, the former ſeems better adapted for the waſhing, or bleaching of linen; and is found not to alter the colour of fleſh-meat to a red tinge by boiling, which Dr. Heberden obſerved of ſeveral of the ſpring-waters in the city of London, and, with great propriety, attributes the ſame to the preſence of the nitrous acid. Further, no coagulation is produced by its ad-

ad-mixture with milk, or turbidneſs upon boiling; neither yet, on the addition of the liquids called re-agents, will it ſenſibly loſe its tranſparency, as is the caſe frequently with the hard waters. Laſtly, for boiling leguminous vegetables, for mixing with the farinaceous ſubſtances, as rice, flour, and oatmeal; in many of the operations of pharmacy; in obtaining extracts; and, as a powerful menſtruum of vegetable bitters and aſtringents, ſoft water is preferable to hard. So infuſions of malt, tea, and coffee, have their qualities extracted much ſooner and more completely by the former than by the latter *.

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* Neither malt, nor tea, produce any ſoftening effect on the hard water in which they are infuſed, but only ſubſtitute one taſte for another: that, in fact, the wholeſomeneſs of malt-liquors greatly depends upon the purity of the water employed. Table-beer, drawn from the barrel about ten days after it had been brewed, curdled with ſoap; as did alſo ſtrong infuſions of green and bohea tea, in boiled, hard water.

Dr. Mead recites the caſe of a lady, whoſe life had been formerly imbittered by repeated attacks of cholic, until ſhe was adviſed by her phyſician, to refrain from drinking, as ſhe uſually did, beer brewed with well-water: and ſo evidently was the reſtoration of her health, owing to ſuch injunction, that the omiſſion of it as conſtantly brought on a return of ailment. So ſays Percival, whether the water is taken by itſelf, or mixed with

The hard waters are, notwithſtanding, better on ſome few occaſions: as in the dreſſing of fiſh; in the boiling of greens; in the making of ſtarch; in the rincing of ſoap out of linen, after it has been waſhed; in the dying of ſtuffs of a looſe contexture, ſuch as callico, fuſtian, and cotton: alſo, for dying of black, red, and other colours, which require aſtringency; and, if we may believe Dr. Rutty, for extracting a tincture, of a deep hue, from logwood, Brazil, ſena, rhubarb and calc. Beſides, they are remarkably indiſpoſed to corrupt, and even preſerve putreſcible ſubſtances for a conſiderable length of time; therefore, ſeem beſt fitted for carrying to ſea.

The freezing of water eaſily, is thought, by ſome, to be a proof of its purity: but this has been expreſsly denied by Hoffman and Haller; and likewiſe,

with wine, or brewed into beer, it ſtill retains in part its original impurities, and cannot fail to occaſion ſome morbid changes in the body: on the robuſt indeed, he adds, its action may perhaps be tardy and imperceptible, yet the tender and valetudinary will feel themſelves ſooner and more ſenſibly injured by it. We are, therefore, to conceive the powerful influence of ſlight, but continued cauſes, on the human frame; and how a ſmall portion of heterogeneous particles, in this univerſal diluent and vehicle, of all our aliment, can, from daily accumulating, lay the foundation of diſeaſe.

wiſe the experiments of Dr. Blagden, confirm to us, that the more turbid and harder the water, the ſooner it congeals.

It is a long eſtabliſhed obſervation, that the beſt waters are the ſooneſt heated and cooled *; and that they evaporate in the ſhorteſt time, and with the leaſt degree of heat. Theſe effects ſeem to me owing, in ſome meaſure, to a more perfect fluidity, by which their parts are more eaſily ſeparated and carried off.

Fiſh, if well taſted, indicate, in general, the wholeſomeneſs of the water they inhabit; and the health of the brute animals who partake of it for their only drink, affords another indication; for, if theſe thrive, there is every preſumption that the ſame water will operate alike on the human ſpecies.

We then readily applaud the wiſdom of our forefathers, in examining the livers of cattle offered up in ſacrifice, wherever they deſigned building a town, or pitching an encampment; for, in whatever ſituation this viſcus ſhewed firm and ſound, there ſettlements were planned, and fortifications erected;

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* Hippocrat. Aphoriſms, lib. 5. Celſus, lib. 2. cap. xviii. Newmann's Chemiſtry, p. 259.

erected; if, however, it appeared of a lax texture, or otherwiſe diſordered, the people ſpeedily moved off, juſtly concluding, that the ſame food and water would prove, in a ſimilar manner, injurious to themſelves; and, in juſtification of which, Dr. Cleghorn gives us to underſtand, that, at Minorca, where the waters of the ſprings and rivulets are often brackiſh, and always hard, abdominal indurations, accompanied with flatulency and indigeſtion, ſeem peculiar to the inhabitants; and adds, what is worthy our notice, that viſceral obſtructions are there likewiſe incident to brutes.

Good water, though ſo very penetrating, eminently poſſeſſes mildneſs; for, if of the ſame preciſe heat as our bodies, on being applied thereto, it excites no ſort of ſenſation: on the contrary, ſo great is its lenient virtue, that, if laid on gently to any painful, diſtended, or naked, excoriated part, it immediately allays the pain, and this probably, as well from its levity, as from its temperature.

The pureſt water is beſt fitted to unite with the animal fluids, or permeate the ſmall veſſels of the machine; alſo, quenches thirſt eaſily, and goes off readily by the ſecretions, eſpecially by perſpiration.

Thus, quoting the late Dr. Lewis, ſimple fluidity; univerſal innocence, or the abſence of any quality, that can offend the tendereſt organ; miſcibility with all the animal fluids, in a ſtate of perfect health; a diſpoſition to paſs off, by the cutaneous pores, more ſpeedily and more plentifully than by the kidnies; in conſequence, perhaps, of its total want of irritation; comprehend the principal part of its medical character.

From hence we are able to derive a clearer judgment of the properties of different waters; and to what degree they can be naturally improved or vitiated, or by art rendered more pure. Any further knowledge in this way, is acquired only by chemical experiments, ſuited to the nature of them, and by inveſtigating, from theſe appearances, their real origin, and the changes made in them; but experience and careful obſervation on their effects when taken, muſt determine how far they may be uſeful or prejudicial to our conſtitutions.

To conclude:——Since the nature and quantities of Mineral Waters can only be aſcertained by a ſeries of experiments and obſervations, inſtituted on the ſpot, it were earneſtly to be wiſhed, that a

NEW AND ACCURATE ANALYSIS OF ALL OUR PRINCIPAL SPRINGS THROUGHOUT THE KINGDOM, was undertaken, BY AUTHORITY, as a matter of PUBLIC CONCERN.

Without intending myſelf the imputation of arrogance, may I preſume to add, that, under ſo noble a patronage, I ſhould feel the ſtrongeſt inducement to make a tender of my ſervices on this important occaſion.

FINIS.

X

ERRATA.

Page 2, line 5, for *morever* read *moreover.*
—— 3, — penult. notes, for *Jacemus* read *Tacemus.*
—— 5, — 9, for *them* read *it.*
—— 6, — 2, for *vegetatables* read *vegetables.*
—— 20, — 10, for 9° mark 98°.
—— 24, — penult. for *their* read *its.*
—— 31, — 15, for 10° read 120°.
—— 37, — 8, for *were* read *was.*
—— 41, — 4, for *in* read *is.*
—— 51, — 9, after *water* make a *comma.*
—— 55, — 12, after the word *diſturbance* make a *comma.*
—— 56, — 3, notes, for *infringing* read *impinging.*
—— 71, — 7, for *fixed* read *fired.*
—— 78, — 1, for *has* read *have.*
—— 86, — 1, for *on* read *in.*
—— 98, — 7, for *tendancy* read *tendency.*
—— 105, — antepenult. for *ſuffieiently* read *ſufficiently.*
—— 106, — 15, for *impoſſibility* read *improbability.*
—— 112, — 2, for *other* read *others.*
—— 115, note, for *Mid.* read *Med.*
—— 121, — 2, (notes) after *other* read *body.*
—— 123, — 22, for *coolneſs* read *ſaltneſs.*
—— 127, — ult. for Dr. *Butter* read Dr. *Butler.*
—— 128, — 17, for *ditto* read *ditto.*
—— 134, — 10, for *ebulition* read *ebullition.*
—— —, — 25, for *perſwaded* read *perſuaded.*
—— 136, — 8, dele *a.*
—— 139, — 18, for *naſcetur* read *naſcitur.*
—— 152, — 22, for *quantities* read *qualities.*

CONTENTS.

PART I.

Page
Introduction —— —— 1
Converſion of Water into Earth —— 6
Conglaciation of Water —— —— 17
Liquidity of Water – —— – 48
Fluidity of Water —— —— 63
On the Compoſition of Water —— 69

PART II.

On the Medicinal Qualities of Water —— 81
A comparative View of the different Waters — 88
The Correction of Waters —— —— 118
The more obvious Characters of ſalubrious Water 144